SCHLICH'S

MANUAL OF FORESTRY.

VOLUME II.

SILVICULTURE.

BY

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SILVICULTURE.

INTRODUCTION.

Silviculture literally means the culture of forests, that is to say all measures connected with the formation, preservation and treatment of forests. In practice, however, the word forestry is used to express and comprise all this, while by silviculture, in its narrower sense, is understood the formation, regeneration and tending of forests, or woods, until they become ripe for the axe. Silviculture, in the latter sense, teaches how a forest, or wood, can be produced and guided to maturity so as to realise in the most advantageous manner the object which the proprietor has in view.

The object, for which a particular forest is maintained, depends on the will and pleasure of the owner, in so far as his freedom of action is not limited by rights of third persons, or by legal enactments. The object itself can be one of many, and of these the following may be mentioned by way of illustration :—

1. To yield produce of a definite description, for instance trees and shrubs of special beauty, or trees giving a certain kind of timber, or other produce fit for particular purposes, such as grass, turpentine, caoutchouc, etc.
2. To produce the greatest possible quantity of wood or other produce per acre and year.
3. To produce the highest possible money return, per acre and year.
4. To produce the highest possible interest on the invested capital.
5. To produce certain indirect effects; for instance, to

influence the climate, to regulate the drainage of the country, to prevent landslips or avalanches, to arrest shifting sands, etc.

In each of these and other cases, the particular species of tree to be grown and the method of treatment are likely to differ, and it is the business of the forester to select those species and methods which realise the object of management most fully and in the most economic manner. More especially, the forester must always consider what effect the species and the selected method of treatment are likely to have on the property, and he must remember that any exceptional strain put upon the soil for more than a limited period, in order to realise an exceptional effect, must be followed by a corresponding period of relaxation. Unless this is given, the soil, in the majority of cases, will deteriorate, and it may ultimately become absolutely sterile. Such an exceptional strain may suit the special requirements of a particular owner, but is not in the interest of the general community. Political Economy teaches that the correct mode of procedure points to the careful preservation of the productive powers (or factors) of any given locality, so as to render possible the production of the same effect, or an increased one, regularly and indefinitely.

Experience has shown that in forestry the safest method of preserving the productive powers of a locality consists in maintaining uninterruptedly a crop of forest vegetation on the area. The more frequently and the longer the ground is uncovered and exposed to the full effects of sun and air currents, the more, in the majority of cases, is the productive power liable to be reduced.

The subject of Silviculture will be treated under the following headings:—

Part I.—The Foundations of Silviculture.
,, II.—The Formation and Regeneration of Woods.
,, III.—The Tending of Woods.
,, IV.—Silvicultural Notes on Forest Trees.

PART I.

THE FOUNDATIONS OF SILVICULTURE.

THE FOUNDATIONS OF SILVICULTURE.

The natural forest vegetation of the various parts of the earth consists of a large number of species of trees and shrubs, each of which has its peculiar mode of growth, and thrives best under certain conditions. As the latter differ according to latitude, longitude (indicating the distance from the ocean or large sheet of inland water), elevation, soil and other circumstances, it follows that each part of the earth has its peculiar forest flora. And yet, the same type of forest is found in parts of the earth which are separated by long distances; at any rate, some of the genera are the same, although the species may differ. How this separation has come about, cannot be discussed in this book, but it may safely be assumed that the local conditions in all these cases must, at any rate approximately, be the same. Hence, it may be said:—(1) That the species found in such localities are interchangeable, and (2) that the principles which govern the selection of species and their treatment must, practically, be the same; in other words, the fundamental laws of silviculture hold good in all these cases. The theory of silviculture can be learnt in any part of the earth, but it remains to adapt it to the local conditions with which the forester has to do. In this volume, the examples required to illustrate the laws of silviculture will be taken chiefly from the timber trees ordinarily growing in Western Europe on the fiftieth degree of latitude, and the country immediately to the north and south of it, with the addition of a few species introduced from other parts of the earth which deserve extended cultivation in Western Europe.

Of the species here in question, only a limited number possess the faculty of forming by themselves healthy and flourishing woods for any length of time, while others will

obtain perfection only if they are mixed with the former. Species are called *ruling* or *dependent*, according to whether they belong to the first or second class. If the more important timber trees, growing in the above-mentioned region, are arranged accordingly, the following lists are obtained:—

Ruling Species.

Decidedly ruling.—Beech, silver fir, Norway and Sitka spruce, Douglas fir, Scotch pine, hornbeam.

Conditionally ruling.—Oak, Tyrolese and Japanese larch, common alder, birch, willows, Austrian pine, Corsican pine, mountain pine, Weymouth pine, sweet chestnut.

Dependent Species.

Of these may be mentioned: Ash, Norway maple, sycamore, poplar, elm, lime, white alder, Cembran pine, Robinia, and others.

Although the biological characteristics of these and other species have been carefully studied for many years, the subject has by no means been exhausted, because the factors which affect the growth of trees vary constantly, and moreover some of these factors are as yet imperfectly understood. The experience so far gathered will be found in the succeeding chapters. It is that experience which must guide the forester in the selection of species for a particular locality, and of the subsequent method of treatment.

The subjects which claim attention will be dealt with in the following four chapters:—

Chapter I.—Locality in Relation to Forest Vegetation.
,, II.—The Development of Forest Trees.
,, III.—Character and Composition of Woods.
,, IV.—The Silvicultural Systems.

These are matters which govern all forest operations, not only the formation, regeneration, and tending of woods, but also the determination of the yield, the preparation of working plans, and the ultimate utilisation of the forest produce.

CHAPTER I.

LOCALITY IN RELATION TO FOREST VEGETATION.

When a plant germinates on the surface of the earth, it sends its roots into the soil, and its stem into the air. The soil, assisted by the subsoil, provides to the plant the means of stability and nourishment; the atmosphere overlying the soil furnishes certain nourishing substances, heat, light, and moisture. Hence, the soil, including subsoil, and the atmosphere are the media which act upon forest vegetation, and they together are in silviculture called the "*locality*." The active agencies or *factors* of the locality depend on the nature of the *soil and the climate*, the latter being governed by the situation. The sum total of these factors represents the *quality* or *yield capacity* of the locality. The forester requires to be well acquainted with the manner in which soil and climate act on forest vegetation, in order to decide in each case which species and method of treatment are best adapted, under a given set of conditions, to yield the most favourable results. The detailed consideration of the laws which govern this branch of forestry finds a place in the auxiliary sciences, such as Physics, Chemistry, Meteorology, Botany, Mineralogy, and Geology. A sufficient knowledge of these branches of science is assumed, so that here only their application to Silviculture need be considered.

The chapter will be divided into the following sections:—

Section I.—The Atmosphere.
" II.—The Climate.
" III.—The Soil and its Effect on Forest Vegetation.
" IV.—Effect of Forest Vegetation on the Locality.
" V.—Assessment of the Quality of the Locality.

SECTION I.—THE ATMOSPHERE.

The earth is surrounded by gaseous bodies, which move with it, and collectively are termed the atmosphere. Owing to the weight of its component parts, the atmosphere is densest close to the surface of the earth, and becomes thinner with increasing distance from the earth, passing gradually into space.

The substances of the atmosphere of special importance in Silviculture are :—

(1.) Oxygen and Nitrogen.
(2.) Carbon dioxide.
(3.) Moisture.
(4.) Solid bodies.
(5.) Ammonia and Nitric Acid.

1. Oxygen and Nitrogen.

The chief constituents of the atmosphere are 21 parts of oxygen and 79 parts of nitrogen in a mechanical mixture. No chemical process is required to separate oxygen from nitrogen; as a matter of fact, all porous bodies possess the faculty of taking oxygen from the atmosphere, without entering into a chemical combination with it. Amongst such bodies are the soil, leaves, bark, and roots of plants. Until a comparatively late date it was believed that plants could not take nitrogen direct from the air. It has now been proved that certain plants, including various forest trees, can do this, and further investigation will doubtlessly lead to additional discoveries in this respect.

Although the leaves of plants take up oxygen, they exhale greater quantities of it under the effect of light; the latter is the result of the decomposition of carbon dioxide by the leaves, which retain the carbon and surrender the oxygen. Thus, plants are powerful agents in the production of oxygen.

The action of the air in the soil is chiefly two-fold; it causes the evaporation of moisture and the decomposition of organic matter. The air which penetrates into the fissures and interstices of the soil becomes charged with vapour and carbon

dioxide; it is then forced out of the soil by every rise of temperature, and replaced by fresh air during cooling. The extent of this change of air depends on the degree of porosity of the soil and the daily range of temperature; the greater these are, the more rapidly will moisture and organic matter (humus) disappear. The daily range of temperature is seriously affected by the degree of protection which the soil receives from forest vegetation; it is greatest in fully exposed soils and smallest in soils under the shelter of a full crop of trees, especially if the foliage offers lateral as well as vertical shelter against sun and air currents. In the latter case, the humus is generally carefully preserved, in the former it disappears rapidly.

2. Carbon Dioxide.

About 0·0004 parts of the volume of the atmosphere consist of carbon dioxide which is received from a variety of sources, as combustion or decomposition of plants, the breathing of animals, volcanoes, spring water issuing from the interior of the earth, combustion of coal and lignite, from various minerals as for instance calcium carbonate. Of these, the first is by far the most important source of supply.

Plants, except certain parasites and saprophytes, take the carbon dioxide which they require through their leaves from the atmosphere. Subsequently, when they die and are decomposed, their carbon is converted back into carbon dioxide, and returned to the atmosphere; hence, plants form an important link in the movement of carbon dioxide.

3. Moisture.

The atmosphere is the medium through which the dry land receives the greater part of the necessary moisture. Sheets of water (the sea, lakes, rivers, etc.) and moist bodies evaporate moisture, which, as vapour, rises in the atmosphere, until it is again condensed into water. It either settles as dew on cool objects, or falls as rain, snow, or hail from the cloud region to the ground. Plants, being moist bodies, take

part in the circulation of moisture; they receive it from the soil through the roots, and evaporate it through the leaves.

In this perpetual circular motion of moisture, several points are of special interest to the forester. By the action of heat, water is converted into vapour, and consequently evaporating bodies become drier and cooler, and reduce the temperature of the surrounding layers of air in their effort to replace the expended heat. It follows that the rate of evaporation is, amongst other influences, governed by the temperature, which depends upon the climate. There is, however, another reason why the rate of evaporation depends on the temperature:—The maximum of vapour which saturated air can hold rises at a more rapid rate than the increase in temperature. It follows that air of a high temperature can hold more vapour than at a low temperature, and yet the relative humidity may be smaller in the former case. Hence, evaporation is more rapid in summer than in winter; it is generally also greater during the day than at night.

4. Solid Bodies.

The atmosphere always contains a certain quantity of organic and inorganic solid bodies, which are kept in suspension in consequence of their minute size and lightness. These bodies are carried about by air currents and may be deposited in certain localities. Again, when vapour is condensed and falls to the ground as rain, snow, or hail, it carries with it a certain quantity of these solid bodies, which differs according to locality; the mineral part of these deposits is not inconsiderable compared with that which is required annually for the production of timber on a fully-stocked area. Amongst the substances thus brought to the ground are calcium carbonate, magnesium carbonate, sodium chloride, calcium sulphate, ferric oxide, alumina, silica, organic nitrogenous matter, etc. Direct analysis has shown that upwards of 300 lb. of these substances have been deposited on an acre of land in one year, a quantity more than sufficient

to provide for that contained in a heavy increment of wood laid on during the same period. In other cases, observations have shown that the quantities deposited are considerably less than 300 lb. per acre. The actual amount depends in the first place on the amount of rainfall.

5. Ammonia and Nitric Acid.

Limited amounts of these important substances are contained in the atmosphere; they supply nitrogen to forest plants in considerable quantities, especially for the formation of seeds.

A certain quantity of ammonia and nitric acid is brought into the soil by the annual rainfall; where the latter is heavy, the quantity of the substances thus obtained by the soil may be sufficient for all the requirements of forest growth, but where it is light, this will not be the case.

As already stated, certain plants (Leguminosæ) can take nitrogen direct from the air. Further investigation may show that the assimilation of nitrogen by the plant from the air is far more extended than is at present known.

SECTION II.—THE CLIMATE.

By climate is understood the local peculiarities of the atmosphere in respect of temperature, degree of clearness, moisture, and rest or motion. As already indicated, the climate of a locality depends on its situation.

The climate of a locality is of greater influence upon the life and growth of plants than the degree of fertility of the soil; hence, it demands the forester's special attention. Generally speaking, the climate of a locality depends on:—

(1.) Latitude and longitude, or geographical position.

(2.) Elevation above the level of the sea.

(3.) Aspect and gradient.

(4.) Shape of the surface and the condition of surroundings.

Each of these affects the heat, light, and humidity of a locality, which are the agencies determining the commencement and course of the annual phenomena of vegetation.

1. Heat.

Heat affects plant life in various ways. In the first place, it is necessary for transpiration by the plants and evaporation from the surface of the earth; secondly, it governs the movement of the air, which produces a thorough mixture of its different ingredients, as well as that of warm and cold, dry and moist, clear and hazy air.

The heat required by plants for transpiration and growth must be supplied to them by the atmosphere, either directly or through the soil. If these are themselves deficient in heat, transpiration must cease as soon as the plant has expended the store of heat which it contains. This, however, frequently does not take place until serious damage has been done to the plant; in other words, the temperature of the plant may be so far reduced that the freezing point is reached, although the temperature of the surrounding air is still several degrees above that point.

The important source of atmospheric heat is the sun; hence, the temperature of a locality depends in the first place on its *latitude*. The mean annual temperature decreases with the distance from the equator, because the sun's rays strike the earth more obliquely in proceeding north or south from the equator towards the poles. In the centre of Europe and in the vicinity of the 50th degree of latitude, the temperature decreases one degree for about every 61 miles on proceeding north. The climate thus produced is frequently called the *geographical* or *solar climate*. It exists practically nowhere on the earth, because it is modified and converted into the *physical* or *local climate* by a series of influences, amongst which the following deserve attention:—

a. Elevation above the Level of the Sea.

The temperature falls with the elevation above the sea. In the Alps, the fall is one degree for every 300 to 400 feet of elevation; it is about 900 times as rapid as the fall caused by increasing latitude. The effect of elevation upon temperature

is subject to modifications. High plateaux of considerable extent show a milder climate than that calculated for their elevation, because the sun's rays are more intense than at the level of the sea. On the other hand, wind currents exercise a considerable effect, so that isolated peaks have, as a rule, a comparatively rough climate.

Cold air, owing to its weight, glides down slopes and may become stationary in valleys and low land generally, producing locally and temporarily a lower temperature than that which corresponds to the elevation of the locality. Hence, in such localities late and early frosts are more common than in localities which are under the influence of a free circulation of the air.

b. Presence of Extensive Sheets of Water.

Owing to a difference of temperature, and the consequent exchange of air between dry land and sheets of water, the latter cause the climate of the former to be more equable, the temperature being lower during the day and higher during the night. It is chiefly for this reason that the longitude of a locality, by affecting its distance from the ocean or other extensive sheets of water, influences the local climate.

c. Aspect and Gradient.

The angle at which the sun's rays strike the soil depends on the aspect of the locality; hence, in the northern hemisphere, aspects between south-east and south-west are the warmest, and those between north-east and north-west the coldest. The degree of the gradient further modifies this effect, which also depends on the latitude.

The aspect affects the temperature also in exposing a locality to air currents, or protecting it against them. This effect may be favourable or the reverse according to the nature of the air currents.

d. Presence or Absence of Forest Vegetation.

Localities which are bare of vegetation are struck by the full force of the sun's rays, causing the temperature at the

surface of the soil to rise. At the same time, air currents sweep unimpeded over such localities, causing a rapid change of the atmosphere.

On localities covered with a full crop of forest vegetation, the sun's rays strike the crowns of the trees: the heat, absorbed by the air at some height above the ground, penetrates only slowly through the leaf canopy to the layer of air below it and thence to the soil. During the night again, the leaf canopy prevents, or at any rate reduces, radiation. It follows that the air in forests is cooler during the day and warmer during the night than the air on bare localities. This effect is intensified by the fact that the foliage of the trees impedes the force of air currents.

Observations have established the following facts:—

(1.) The climate of wooded countries is more equable than that of open countries.

(2.) The mean temperature of soil and air in wooded countries is somewhat lower than that of soil and air in bare countries. This reduction of temperature would ordinarily act beneficially in warm southern countries, while it may become injurious in cold northern countries, where the temperature is already lower than is desirable.

(3.) The greatest difference occurs in summer, next in spring, then in autumn, and it is very small in winter. It follows that in forests the commencement of vegetation in spring is retarded. This may be beneficial in preventing damage by spring frosts, limiting the formation of inferior spring wood, etc.; on the other hand, it shortens the growing season, and delays the sprouting of seeds in spring.*

Heat is a most powerful agency in the distribution of plants on the earth; the species change with increasing latitude, elevation, and other influences which govern the temperature. This applies to forest trees as well as other plants.

Attempts have been made to ascertain the *absolute* sum of heat required annually by the more important forest trees,

* For further details on these questions, see Volume I.

which have been enumerated in the introduction of this part, but so far the available data are of limited use in silviculture. Moreover, it is beyond doubt that the mean temperature of the year is much less important to forest trees than the temperature which prevails during the growing season.

It has been stated* that a mean temperature of 50 degrees Fahrenheit during the four principal vegetating months (May, June, July, August) is the limit within which tree forest can exist; if it is lower than that, only shrubs are found. That minimum is met between the 65th and 70th degrees of northern latitude, or at an elevation of 7,500 feet in the Alps and at about 14,000 feet in the Himalayas. It varies, however, according to aspect and other local conditions. As to the maximum temperature supportable by tree growth, it may be stated that it does not exist on the earth; if forests are absent in certain parts, it is due to a deficiency of moisture, or other adverse influences.

A very low winter temperature reduces the number of species which can support it. Of European species, spruce, birch, willow, larch and Cembran pine can survive a temperature of −50 degrees Fahrenheit; others succumb at considerably higher temperatures, even in their natural home. As a consequence, the character of forest vegetation changes from the tropics on going north. The former contain, where the climate is not modified by elevation, palms, bamboos, and broad-leaved species producing some of the best timber of the earth, such as teak, mahogany and ebony. Going north in the old world to the shores of the Mediterranean, forests of cork oak are found; in Italy, olive and chestnut appear, gradually giving place to ash, sycamore, beech, birch, and certain species of pine. In Switzerland and South Germany, silver fir and spruce gain ground, but the former disappears on approaching the North Sea. The countries round the Baltic contain forests consisting chiefly of Scotch pine, spruce and birch; in Siberia, larch is found over extensive areas. These latter species are

* Mayr, Waldbau auf naturgesetzlicher Grundlage.

accompanied by willow, alder and poplar. Further north, the species become smaller and of slower growth, until brushwood alone remains. Mayr suggests the following division into zones:—

1. Tropical forest zone, which he calls the *Palmetum*.

2. Sub-tropical forest zone—evergreen oaks, laurels etc.—*Lauretum*.

3. Temperate warm zone of deciduous broad-leaved trees, *a*. the warmer half—*Castanetum*; *b*. the cooler half—*Fagetum*.

4. Temperate cool zone—firs and larches—*Picetum* or *Abietum* or *Laricetum*.

5. Cold zone to the limit of forest—*Alpinetum*, *Polaretum*.

Each of these zones can be met, either on going north or on rising in mountains.

Speaking generally, the number of genera and species decreases from south to north. The consequence is that mixed woods prevail in the tropics and sub-tropics; in the Castanetum pure woods commence, and they prevail in the Picetum.

Every species thrives best in the centre of the zone which is its own; it falls off towards the upper and lower limit of the zone whether produced by latitude or elevation. This holds good as regards shape of stem, production of volume, and quality of timber.

The suitability of exotic trees depends on their finding in the new locality conditions which coincide with those of their natural home; in other words, that the locality comes at any rate near their natural *optimum*. If this is not the case, the danger from frost, and especially late frost in spring, is against a successful introduction of the species.

Coming now to the relative heat requirements of the several species here under consideration, the following scale is suggested:—

It is greatest in: Common elm, sweet chestnut, pedunculate oak.

Somewhat smaller in: Sessile oak, Austrian pine, silver fir, beech, Weymouth pine, lime, Scotch pine, Douglas fir.

Less again in: Norway maple, birch, sycamore, ash, alder, hornbeam, spruce.

Smallest in: Larch, Cembran pine, mountain pine.

The different degrees of heat requirement produce many phenomena of interest to the forester, of which the following may be mentioned :—

(1.) On the same latitude, the several species, if left to natural selection, are found at different elevations. While the Cembran pine finds full development near the upper limit of tree vegetation (up to 7,500 feet in the Alps), the larch and next the spruce prefer a somewhat lower zone; lower again appear beech, silver fir, and sessile oak, while the pedunculate oak and Scotch pine flourish in the low lands.

(2.) A species, which prefers a certain altitude in one locality, will descend towards the level of the sea with increasing latitude, or ascend with decreasing latitude.

(3.) At the same altitude, the more heat requiring species will seek the warmer southern aspects, and the less heat requiring species the cooler northern slopes.

(4.) A species, which is naturally found on a northern aspect at a low elevation, will seek a southern aspect at a higher altitude.

It must not, however, be overlooked that the actual distribution is affected by many other influences besides heat, and that the above theories are only of an abstract nature.

The effect of *frost* on the various species is intimately connected with their heat requirement. Trees suffer, as a rule, little from winter frosts within the region of their natural distribution, but frost occurring during the growing season may do considerable damage, especially during spring (late frosts) immediately after the tender leaves and shoots have been put forth, and during autumn (early frosts) before the newly-formed wood has had time to ripen. Many influences and circumstances contribute towards the occurrence of late and early frosts. Sometimes they are caused locally, especially in low lying or confined localities, in consequence of excessive

radiation, evaporation, the descent of cold air from higher localities, and absence of air currents; in other cases, they are due to cold winds. The several species vary much in their bearing towards late and early frosts; in a general way the following classification will hold good:—

Most subject to suffer from late frosts are: Ash, Robinia, sweet chestnut, beech, silver fir.

Somewhat less: Oak, Douglas fir, Norway maple, sycamore, spruce, alder.

Less again: Lime, hornbeam, elm, birch, larch, aspen, Corsican, Austrian, Weymouth, and Scotch pines.

The relative humidity has a decided effect upon the degree to which trees are subject to damage by late frost; the higher it is, the smaller that danger.

The degree of damage depends, apart from the severity of the frost, on the condition of the leaves and young wood, the general health and vigour of the plants, and whether they have been suddenly or gradually deprived of shelter.

The damage occurs, generally, during the process of thawing, after freezing. The more rapidly the plant thaws, the greater will be the damage; hence, it will be greatest on east and south aspects, and smallest on west and north aspects.

Frost may kill the plant outright, or only the leaves and tender shoots. It may also cause cracks in the bark as in beech, or in the bark and wood as in oak.

Trees may also be injured by too high a temperature; more especially scorching of the bark may occur, especially in the case of trees with a smooth bark, as in beech.

2. Light.

The earth receives light from the sun, the source whence heat is supplied. With the exception of certain low forms, all plants require light to enable them to live and grow, as soon as the available reserve materials have been consumed. Without light, carbon dioxide cannot be decomposed by the chlorophyll of the plants. Sun light decreases in intensity

on going north, but increases on rising. Diffused light decreases on going north or rising in mountains. Diffused light is believed to be at least as favourable for assimilation as direct sun light. This would explain why the crowns of trees develop evenly all round the stem.

During the process of germination light is not required, because the embryo is developed by means of substances deposited in the seed. Similarly, the first starting of vegetation in spring can take place with a small amount of light, because it is done by means of reserve materials deposited in certain parts of the plant. As soon as these substances, both in germination and the awakening of vegetation in spring, have been consumed, light becomes absolutely necessary for the preparation of new food materials.

All trees, then, require light for their proper development, but the necessary quantity has its upper and lower limit. Not only too little but also too much light can interfere with the phenomena of growth. If the access of light is reduced to a certain degree, assimilation of the leaves ceases; too much light is accompanied by an increase of temperature. Between the maximum and minimum a degree exists which corresponds with the most favourable development of a species, and which represents its normal light requirement, or *optimum*. It changes with the age of the trees, and is greatest during the period of the principal height growth, smaller during youth and old age. During the time of the development of the buds, the flowering, and the formation of the fruit more light is required than is necessary for growth only. Regarding the absolute quantity of light required by the several species, little is known at present, but much experience has been collected which demonstrates their relative light requirements. On the whole, it is known that certain species cannot thrive unless they enjoy a large measure of light throughout life, while others will bear a certain amount of shade. Accordingly, the former species are termed *light demanding*,

and the latter *shade bearing* or *tolerating*. In a general way, it may be said that trees with a dense crown are shade bearing, and those with a thin crown light demanding, though the light requirement does not always stand exactly in inverse proportion to the density of the crown.

The degree of shade which the several species give differs much. It is greatest in the case of beech, next in that of the species of Abies, then Picea; least strong in oak, pines, birch, and larch. The time during which a species can support shade also differs. Shade-bearing species standing under shade bearers generally die after ten to twenty years; light demanders under shade bearers after about five years; shade bearers under light demanders can live for long periods of time; light demanders under light demanders probably live as long as shade bearers under shade bearers. In warm climates and on fertile soil, species can do with less light than under the reverse conditions. Hence, it is not possible to construct a strictly correct scale according to the light requirements of the several species.

Some species, which are shade bearing, require a certain amount of shelter, or protection, during early youth; they have, therefore, been called "shade demanding." Such a definition is, however, misleading, as these plants require protection against cold, heat, and excessive transpiration, and not against light as such. In young plants of beech and silver fir, for instance, transpiration frequently reaches such a high degree, if they are not sheltered, that they lose water more quickly than they can take it up from the soil, and consequently die. Hence, they require either a sufficient wetting of the soil, or shelter. In the former case more water is available, and in the latter the temperature and thereby the transpiration is reduced. Species are called *tender* or *hardy*, according as to whether they require shelter during early life, or can do without it.

By summing up the available experience of the light requirements of a number of species, scales have been

prepared by various authors, which, though generally agreeing, differ somewhat in details. The following scale begins with the most light demanding species and finishes with the most shade bearing. Lime and Weymouth pine stand in the centre of this scale; the species above them are considered light demanding, and those below shade bearing, the degree in each case depending on the distance from the centre line.

(1.) Larch, birch.
(2.) Scotch pine, poplars, willows, Corsican pine.
(3.) Oak, ash, sweet chestnut, mountain pine.
(4.) Elm, alder, Austrian pine.
(5.) *Lime, Weymouth pine.*
(6.) Norway maple, hornbeam, sycamore, Cembran pine, hazel, Thuia, Douglas fir, Tsuga.
(7.) Spruce.
(8.) Silver fir.
(9.) Beech.
(10.) Yew.

The above scale represents only general averages. In reality, the degree of light requirement is subject to considerable modifications caused by the peculiarities of each locality. Generally, all species bear more shade on good, fresh soil than on poor dry ground, a fact which is indicated by the density of the crown. The Scotch pine, for instance, grown in fresh soils in countries near the sea looks quite different from the same tree seen in continental countries, and stands considerably more shade than the latter.

The length of the growing season also influences the degree to which a tree will stand shade. A certain total quantity of light is required to complete the annual cycle of development; hence, a more energetic effect of light is wanted in localities with a short growing season, such as high elevations, or high latitudes. A species, which stands a certain amount of shade at the level of the sea and in a southern climate, may become light demanding at a considerable elevation, or in a northern climate. Again, in foggy air, under a

covered sky, or on northern aspects, the same species stands less shade than in clear air, under a sunny sky, or on southern aspects. In this respect it must be remembered that the actual intensity of the light is somewhat greater in high mountains than in low lands.

The health of the trees is also of importance. Strong healthy plants with a good root system stand more shade, and for a longer period, than weak plants.

Light and shade in relation to tree growth are of the greatest importance in practical silviculture, especially in the regeneration and tending of woods, the composition of mixed woods, etc. In each of these cases the light requirement of the species must be fully considered, or serious mistakes may be made. The most important period in this respect is early youth, because at that time several species require some shelter, either against heat or frost. If that shelter, on the other hand, is excessive the young trees may be permanently injured, or even die. When a plant has stood in shade for some time, the activity of its leaves is reduced, and it takes some time, after the removal of the shelter, before the increased light produces increased assimilation and visible activity, because fresh organs, fitted for the altered conditions, must be produced. In all such cases it is best to remove the cover gradually and not all at once. If the plant has stood in shade for a considerable period, it may no longer be capable of developing into a tree of normal size. As long as several strong buds are found, especially near the top, this is not to be feared, but the recovery of plants with a few miserable buds may be considered as hopeless.

3. Moisture.

The first question for consideration is, to what extent moisture in the air is necessary or beneficial to plant life. The investigation of this problem meets with great difficulty, because it is often difficult to separate the effect of air moisture from that of soil moisture. Only meagre data are available,

as far as trees are concerned, and further investigation is required, before they can be of general practical use in silviculture. It is known that some species, such as spruce, alder, maple, ash, and next to these, silver fir and beech, thrive generally better in moist than in dry air. It is also a fact that spruce appears naturally over extensive areas in high situations and near the sea shores of northern Europe, that is to say, in localities with a comparatively moist air, while it thrives but indifferently in continental situations with a dry air. The Scotch pine, on the other hand, appears over extensive tracts in continental dry climates, and at the same time flourishes in the moist insular climate of Great Britain and Ireland.

Apart from the fact that trees take up moisture through their organs above ground, the atmospheric moisture is of the highest importance, for the following reasons:—

(*a.*) It supplies the soil with water, whence it is taken up by the roots of the trees.

(*b.*) It governs the degree of transpiration from the leaves of the trees.

The degree of transpiration depends on the degree of saturation of the air and the temperature; hence, relatively dry air causes rapid transpiration, while the latter ceases when the air becomes saturated. The degree of transpiration, in its turn, governs the rapidity with which fresh water, charged with raw materials, is taken up by the roots.

Apart from inundation or ground water, the soil receives water from the atmosphere in the shape of precipitations, as dew, rain, snow, hail, and a certain amount by means of its hygroscopic nature. The quantities differ enormously in different climates and localities, from almost nothing to over 500 inches a year. Precipitation cannot take place unless the air becomes saturated. The phenomena which favour an increase in the relative humidity, and thereby induce saturation, are active evaporation and a reduction of temperature. On the one hand, evaporation causes a reduction of

temperature, and on the other, a falling temperature reduces the degree of evaporation; the result is, that saturation and precipitation occur only locally.

As a general rule, a low temperature means a high degree of relative humidity; hence, the latter is greater in winter than in summer; greater at high elevations than in low lands; greater in the vicinity of extensive sheets of water than in continental countries; greater in forest countries than in bare tracts.

Observations have shown that the relative humidity of forest air is greater than that of air in the open country, the difference amounting in Central Europe to as much as 10 per cent. during summer, and about half that amount in winter. The practical value of this fact in silviculture is that radiation of heat is much slower, and the danger of late and early frosts smaller in the forest than it is outside.

Snow and ice have a considerable effect upon trees. During early youth snow may protect forest plants against excessive cold. Later on, a heavy fall of snow, or the formation of ice or rime, may break the branches and tops of trees, or even fell them to the ground, especially if snow and wind act together. The danger is generally greatest in densely grown young woods, more particularly those consisting of conifers or of broad-leaved trees with the dry leaves still adhering to the branches. Shallow rooted trees are more easily thrown than deep rooted species.

Forest trees are also liable to be damaged by hail, which may injure, not only the soft shoots, but also the bark of species with a smooth surface.

4. Air Currents.

The atmosphere is, practically, in constant motion. The principal cause of this is the uneven heating of the earth by the sun. The heat, which becomes free on or near the surface of the earth, warms the adjoining air and causes it to rise, its place being taken by colder air from other parts of the earth.

The ascending air, after cooling, sinks again in its turn. In this manner a circular motion exists between the equator and the poles as well as between dry land and large sheets of water. Owing to a combination of these currents with the motion of the earth, modified wind directions are produced. The prevailing wind directions on the northern hemisphere are, therefore, from the south-west and the north-east, according as to whether the original current started from the tropics or the polar region.

A second cause of wind currents, especially of storms or gales, is the sudden condensation of considerable quantities of aqueous vapour, which forces air to rush from all sides into the space of reduced pressure.

Air currents are of paramount importance to all organic life on the earth, because they produce a thorough mixture of the constituents of the atmosphere. Without them, the land would soon lose all moisture. The motion of the atmosphere ensures a proper distribution of moisture, carbon dioxide, oxygen and nitrogen over the earth.

Air currents may affect forest trees injuriously principally in two ways :—

(*a.*) By unfavourably modifying the temperature and moisture of a locality.

(*b.*) By injuring, breaking, bending, or overturning them.

Dry winds frequently reduce the moisture of a locality to a dangerous degree; moist and cold winds may reduce the temperature, and thus interfere with the healthy growth of the trees. Strong winds may break the leading shoots or side branches, cause trees to assume a curved shape, or even throw single trees and whole woods to the ground.

The damage done to trees by strong winds differs very considerably according to species. Shallow rooted trees, like the spruce, suffer most, while deep rooted trees, like oak or Scotch pine, are much less affected. The most dangerous winds in Western Europe are those which blow from south-west, west, and north-west. Occasionally north-east winds are also dangerous.

SECTION III.—SOIL.

It has already been stated that plants, and more especially trees, require a certain layer of soil, into which their roots penetrate, and which provides them with nourishment and the means of stability. Wherever this layer of soil is deep enough to meet the above requirements, the subsoil is only of indirect importance, but in the case of shallow soils the subsoil has, as a rule, to undertake part of the ordinary functions of the soil. Under any circumstances, the subsoil furnishes the materials from which the mineral parts of the soil are principally derived. Hence, in speaking of the soil, the subsoil is more or less included.

1. Origin of Soil.

All soil is originally the result of the disintegration of the rocks of the earth, with the addition of certain organic substances. In some cases, the soil now overlies the rock from which it has been derived, in others it has been carried away by violent convulsions, or the action of water and air currents, and deposited again in other places. In the first case, the soil is called "*indigenous*," and in the second "*exotic*." The most important form of the latter is alluvial soil, formed by deposits near the sea coast, in river deltas, and inland by water courses and lakes, as well as by the action of air currents.

2. Formation of Indigenous Soil.

The formation of soil is due to a variety of agencies, which are either of a mechanical, chemical, or organic nature.

a. Mechanical Agencies.

Amongst these, heat takes the foremost place. The heating of rocks produces an unequal strain and pressure, which cause them to burst in various directions. Then, if water penetrates into the interstices and freezes, it forces the particles asunder, thus further breaking up the rock. Water is also a powerful agency owing to its dissolving action.

b. Chemical Agencies.

When oxygen and water, which contains carbon dioxide and other acids, come into contact with the rock, they form chemical combinations with its elements. The oxygen acts especially on the metals (as compounds of iron), forming, by the addition of water, hydrates of metallic oxides. This process, accompanied by an increase of volume, destroys the previous cohesion of the rock. Water containing carbon dioxide and other acids penetrates the rock, dissolves its various constituents and carries off several substances, such as lime, magnesia, and potash.

The rate of chemical decomposition depends on the temperature; the higher the latter, the quicker the decomposition. Hence, it is more rapid in tropical than in cold climates.

c. Organic Agencies.

When mechanical and chemical action have commenced the decomposition of the rock, organic action sets in. Lichens, followed by mosses, appear on the surface of the rock, which further accelerate disintegration by keeping the surface moist. Next, the roots of these plants penetrate into the finest fissures and assist mechanical action. In this manner, a soil is gradually formed, which consists of fragments of rock and remnants of dead plants, suitable for the support of more highly organised plants, such as grasses and herbs; these are followed by shrubs and trees, which penetrate with their roots deeper and deeper into the rents and fissures of the rock, and further accelerate disintegration.

When this process has gone on for a sufficient length of time, the outer part of the earth's crust consists of a layer of varying depth which, commencing from below, changes gradually from the solid rock into broken rock, or brash, then into smaller pieces of rock, or subsoil, and ultimately into the formed or surface soil.

At first sight it would appear that the composition and quality of the soil depend solely on the composition of the

original rock, out of which it has been formed. This is, on closer investigation, found to be the case only to a limited extent, because, in the first place, certain important substances, such as potash, magnesia, lime, may be carried away and lost during the process of disintegration; secondly, organic substances are added; and thirdly, the fertility of the soil depends not only on its chemical composition, but also, and often chiefly so, on its physical properties. All that can be said is that certain kinds of rock yield ordinarily a soil of a certain description, but subject to modifications, which depend on the peculiarities of each case. On the whole, the attempt of estimating the quality of a soil by its geological origin alone has almost invariably failed, since the same rock may produce soils of varying chemical composition and physical properties.

3. Composition of Soil.

Soil consists generally of the following substances :—

(A.) Mineral matter, taken from the decomposed rock, or carried to the area by water or air currents.

(B.) Organic matter, being remnants of plants and animals.

(C.) Water, partly liquid, partly in the shape of vapour.

(D.) Gases, such as air, carbon dioxide and ammonia.

A. *Mineral Substances in the Soil.*

The mineral substances form, in the majority of cases, the greater part of the soil; they may be arranged into :—

(*a.*) Earths; (*b.*) salts; (*c.*) acids; (*d.*) metals.

a. Earths.

Silica, alumina, lime, and, next to these, magnesia are the earths which occur most frequently in soils.

Silica is represented chiefly in *sand.*

Silica combined with alumina forms *clay.*

Clay with sand forms *loam.*

Lime appears principally as calcium carbonate in calcareous soils, also as calcium sulphate in gypsum.

Magnesia is most frequent in dolomite, though smaller quantities are found in most other soils.

b. Salts.

The most important salts are :—

Potassium carbonate (potash), sodium carbonate (soda), sodium chloride (common salt), carbonates, sulphates and phosphates of iron and manganese.

The quantity of salts in the soil does not, as a rule, exceed one-half per cent., and rarely one per cent. Larger quantities appear only in certain localities, such as salt plains, in the vicinity of the sea coast or salt springs, and in some peaty and swampy soils; in these cases, they act injuriously on vegetation.

Potassium carbonate is of importance, as forest trees require a fair amount of it. Sodium carbonate in moderate quantities does not act unfavourably. Sodium chloride acts favourably only if present in small quantities. Salts of iron often act injuriously.

c. Acids.

Carbon dioxide and humic acid are the two free acids which generally appear in soils. Other free acids, if they appear at all, do so only temporarily, until they enter into combination with a base.

d. Metals.

Of metals, only iron is of importance in silviculture. It appears as ferrous oxide and as ferric oxide. The former is believed to be injurious to plant life. Ferric oxide may be mixed with soils, and unless the quantity exceeds 10 per cent., it does not act injuriously; on the contrary, most fertile soils contain a certain quantity of it. Oxides of iron frequently assist in the formation of impermeable strata, or pans.

B. *Organic Matter, or Humus.*

By humus is understood in silviculture all organic matter which, in contact with the soil, is gradually decomposed, and

forms in mixture with the upper layer of mineral substances the mould or black earth of the forest. The sources of humus are the annual fall of leaves and twigs (or even whole trees) and dead plants.

The continuous decomposition of humus furnishes several important products. In the first place, the soil receives all the mineral matter contained in the humus (ashes); secondly, a large quantity of carbon dioxide is produced, which accelerates the decomposition of the mineral part of the soil. Finally, humic acid renders many important substances, such as potash, magnesia, lime, etc., soluble in water, so that they become available for the plant.

There are, however, different kinds of humus:—*Mild humus* or *forest humus* is formed, if air and water act in proper proportion upon fallen leaves, moss, etc. *Dry mould* is formed by the action of an excessive supply of air, or rather absence of moisture, on certain plants such as heather. *Acid humus* is the result of decomposition, if there is an excess of moisture and a deficiency of air in the soil. Only mild forest humus acts altogether favourably upon forest vegetation.

C. *Water.*

Water is the most important component part of the soil, as plant life is impossible without a certain quantity of moisture. It affects vegetation principally in the following manner:—

(*a.*) It assists in the decomposition of the rocks.

(*b.*) It assists in the formation of humus, and regulates both the admission of air into the soil and its temperature.

(*c.*) It is an important agent in the process of nourishing and shaping the plant. More especially, it carries through the roots the mineral substances from the soil into the plant.

However favourably a certain degree of moisture in the soil may act, an excess of water, especially if stagnant, is always injurious; it reduces the activity of the soil (by driving out air), lowers the temperature, increases danger from frost, and is liable to render the soil acid.

The soil receives water from one or more of the following sources :—

(1.) From the atmosphere, as dew, rain, snow, hail, or as vapour condensed by the hygroscopic action of the soil.

(2.) From ground water resting in the subsoil.

(3.) From inundations, whether natural or artificial.

Water derived from the atmosphere acts most favourably, provided the supply is suitably distributed over the different seasons of the year, and the soil is capable of retaining moisture sufficiently long during dry weather. Where these conditions are wanting, ground water is likely to act more favourably, because it produces a more even degree of moisture in the upper layers of the soil. Natural inundation water is in many cases objectionable, because it renders the soil too wet at one time, and too dry at others. Artificial inundation, or irrigation, produces very favourable results, but it is generally expensive.

D. *Gases.*

The gases, such as air, carbon dioxide and ammonia, have been dealt with in Section I. of this chapter. It is only necessary to add that the amount of air in the soil varies within wide limits, and that the amount of carbon dioxide depends on the quantity of organic matter in the soil, and the rate at which it is decomposed.

4. Physical Properties of Soil.

The principal physical properties of importance in silviculture are the following :—

a. Consistency,

or binding power, the cohesion between the different particles of the soil. It depends on the chemical composition of the different parts, the degree of division, and the quantity of moisture in the soil. Generally, it is greatest in clay and smallest in sand. An admixture of humus moderates both extremes.

b. Shrinking,

or the reduction of the volume of the soil under the process of drying. It causes cracks in the soil, followed by the exposure of the roots. Heavy soils crack more than light soils.

c. Capacity to hold Water.

It is generally proportional to the percentage of fine earth and humus in the soil.

d. Hygroscopicity,

or the capacity of the soil to attract and condense aqueous vapour from the atmosphere. It depends on the degree of division of the particles, and on the temperature. The finer the division, the greater the hygroscopicity; more vapour is condensed at a low than at a high temperature. Soils rich in humus show the greatest hygroscopicity, next clay, then loam, then lime soils, and it is smallest in sand.

e. Tenacity in retaining Moisture

is greatest in clay soils, moderate in calcareous soils and smallest in sand.

f. Permeability,

or the capacity to let water pass through, is greatest in sand, especially if of a coarse grain, and smallest in clay. Humus soil approaches clay, while calcareous soils and loam stand about half-way between the two extremes. Stiff clays are liable to be altogether impermeable; in many cases the clay of a mixed soil is gradually carried into the subsoil, where it forms an impermeable layer, frequently bound together by oxide of iron.

g. The Power to retain Salts dissolved in Water

depends on the proportion of fine earth in the soil.

h. The Capacity to become Heated

is greatest in sand, and smallest in clay. Calcareous soils approach sand; loam approaches clay. Sand and calcareous soils are generally hot soils, while clay is a cold soil.

i. *General.*

Depth intensifies the effect of the various physical properties. A depth of 4 feet may be considered as sufficient for almost any species, and many can do with considerably less. Where a sufficient depth of soil is not available, the assistance of the subsoil is called in, especially its degree of permeability. Apart from alluvial soil, the depth depends chiefly upon the nature of the rock and soil, the stratification of the rock, the situation, and the general shape of the surface of the ground. The nature of the rock governs the rate at which it is disintegrated. An impermeable subsoil is all the more injurious the nearer it is to the surface, because it makes the surface soil too wet and cold at one time, and too dry and hot at others, apart from the fact that the roots may not find sufficient room for spreading, and that the stability of trees may be endangered.

A vertical stratification and a much crumpled state of the rock act favourably upon the movements of water in the soil and the penetration of the roots; a horizontal stratification, if unaccompanied by crumpling, is generally the least favourable form. Low lands have ordinarily deeper soils than high lands. On ridges and steep slopes the soil is liable to be washed away, while it is collected in depressions. In the former places, the covering of dead leaves is liable to be blown away by wind.

The physical properties are of special importance through their action upon moisture. In this respect, the chemical composition of the soil is of less importance than the admixture of humus and the degree of division of the particles; hence, sand and clay represent, ordinarily, the extremes.

5. Classification of Soils.

For the purposes of silviculture, soils may be classified, either according to their chemical composition, or according to one or other of their physical properties.

a. Classification according to Chemical Composition.

It is out of the question to attempt a classification according to all component substances, nor is it necessary, because the importance of the four substances, sand, clay, lime and humus, outweighs that of all other substances so much, that the latter need not be taken into account in this place.

The subjoined table gives the composition of the ten principal classes of soils (according to Church) :—

Name of Soil.	Percentage of:			
	Clay.	Calcium Carbonate.	Sand.	Organic Matter.
1. Loams or Free Soil	20—30	5—10	50—70	2—5
2. Clays	over 40	under 5	under 50	2—5
3. Clay-sands	„ 30	„ 5	50—70	2—5
4. Marls	„ 30	5—10	under 50	2—5
5. Peaty Clay	„ 30	under 5	„ 50	over 5
6. Sands	under 10	„ 5	over 80	2—5
7. Calcareous Sands	„ 10	5—10	„ 70	2—5
8. Peaty Sands	„ 10	under 5	„ 70	over 5
9. Calcareous	„ 10	over 10	50—70	2—5
10. Peats	„ 10	under 5	under 50	over 35

NOTE.—Lime improves 2, 3, 5 and 8.
Draining improves 2, 4, 5 and 10.
Irrigation improves 6 and 7.

Other soils are :—

Dolomite, a chalky loam with much magnesium carbonate.

Gypsum, a soil which is rich in calcium sulphate.

Salt soil, which contains an excessive percentage of salts, especially sodium chloride.

Ferruginous soil, which contains an excessive proportion of ferric oxide.

According to the preponderance of one or other of the principal ingredients, numerous subdivisions have been made, such as sandy, or marly clays; loamy sand, sandy loam, marly sand, sandy marl, etc.

Clay, loam and calcareous soil are, as a rule, minerally strong soils, while sandy soils are less strong. Humus soil

may be mild, dry, or sour; the first acts very favourably upon tree growth, the two latter unfavourably.

Soils may also be classified according to the rapidity with which the humus is decomposed, as :—

Very active soils: Such as dry porous sand and calcareous soils, in which the decomposition of humus is excessively quick.

Active soils: Such as moderately moist loamy sand, sandy loam and loamy marl, in which the decomposition of humus proceeds at a rate favourable for growth, without actually exhausting the supply of organic matter.

Moderately active soils: Such as stiff clay, wet soil, heather soil, where the decomposition is too slow for a healthy development of most plants.

Inactive soils: Such as peat soil, shifting sand, etc., in which, either from excess of moisture or absence of humus and rest, little or no decomposition takes place.

b. Classification according to Physical Properties.

Of the various physical properties, the degrees of consistency and of moisture are of special importance in silviculture. According to consistency, soils may be classified in the following manner :—

Light soils: All soils which contain much coarse grained sand or much humus.

Loose soils: Such as peat and moor soils, which are elastic and swell during rainy weather; they are also much lifted by frost.

Binding soils: Soils of moderate cohesion, such as fine grained loamy sands, coarser grained sandy loams, calcareous soils, especially marl.

Heavy soils: Such as fine grained loam, clay with coarse sand.

Stiff soils: Such as clay with a limited quantity of fine grained sand.

In classifying soils according to the degree of moisture, a

distinction must be made between the average degree of moisture and the condition of the soil during the growing season, as set forth in the following arrangement:—

Wet soil: Water flows from it without the application of pressure.—Even in summer water runs off in drops on the application of pressure.

Moist soil: On pressure being applied, water falls in drops.—During summer the soil does not become dry beyond one inch below the surface.

Fresh soil: Leaves traces of moisture on the palm of the hand on being pressed.—During summer it does not become dry beyond six inches below the surface.

Dry soil: Has lost the dark colour due to the presence of moisture, but does not fall to dust on being broken.—In summer it becomes dry to a depth of 12 inches within a week after a good soaking rain.

Arid soil: Falls to dust on being broken.—In summer it dries up to a depth of more than 12 inches within a few days after a good soaking rain.

6.—Effect of the Soil upon Forest Vegetation.

In estimating the effect which differently constituted soils have upon forest vegetation, and more especially upon tree growth, the forester is guided by the demands made by the trees upon the soil. Ordinarily, the soil should provide the tree with stability, space for a suitable spreading of the root system, moisture in suitable quantities at all times, and nourishing substances in sufficient quantities and in a condition suitable for absorption by the roots.

Any soil which meets these requirements is fertile for silvicultural purposes, and experience has shown that fertile forest soil must possess the following properties:—

(*a.*) A sufficient depth.

(*b.*) A suitable degree of porosity.

(*c.*) A suitable degree of moisture.

(*d.*) A suitable chemical composition.

a. Sufficient Depth.

The depth is measured by the thickness of the layer of soil, and of that portion of the subsoil which can be penetrated by the roots. In due proportion to depth are the space available for the root system, the stability of the trees, the store of nourishing substances, and the state of moisture in the soil.

The root system differs considerably in the several species; some develop a tap root which is maintained for a shorter or longer period, such as oak, chestnut, elm, Scotch pine, silver fir, maple, sycamore, ash, lime, larch ; others have strong side roots, which send down deep going rootlets, such as alder: others again go to a moderate depth, as beech, hornbeam, aspen and birch ; finally, some spread altogether near the surface, such as spruce. The nature, composition, and degree of moisture of the soil modify the root system to some extent, which in young trees frequently differs from that in a more advanced age.

On the whole, certain species thrive well only in deep soil, while others can subsist in shallow soil, though they prefer the former. The best indicator of the depth of soil is the height growth. A sufficient depth produces full height growth ; with deficiency of depth the height growth falls off.

Trees may be classified as follows in respect of their demands for depth of soil :—

Species which are satisfied with shallow soils : Spruce, mountain pine, birch, aspen, mountain ash.

Species which require moderate depth : Austrian pine, Weymouth pine, beech, hornbeam, black poplar, tree willows, alder, horse chestnut.

Species which require greater depth : Scotch pine, Cembran pine, elms, Norway maple, sycamore, white poplar.

Species which require greatest depth : Silver fir, larch, ash, lime, sweet chestnut, and especially oaks.

At the same time, the roots of these species rarely go to a

depth of 4 feet below the surface, unless they do not find sufficient moisture in the upper layers of the soil, a case occurring in countries with a long dry season.

b. A suitable Degree of Porosity.

Neither too firm nor too loose soils are favourable for tree growth. Too firm soils make the penetration of the roots difficult, if not altogether impossible, prevent the admission of the necessary air, interfere with the movement of water, and incline towards swampiness accompanied by increased danger from frost, strong shrinking and cracking in summer. Too loose soils endanger the stability of the trees, are liable to be carried away by water or wind, suffer from too rapid drying and too rapid decomposition of the humus, and the plants growing in it are subject to frost lifting. The best soils are of middling consistency, such as loam and calcareous soils with a good layer of humus.

c. A suitable Degree of Moisture.

By a suitable degree of moisture is here understood that degree, which corresponds to the natural requirement of any particular species. The more uninterruptedly that degree is maintained throughout the growing season, the more favourable will be the development of the tree.

Apart from climate and subsoil, the condition of the soil itself, its depth, porosity, the nature and proportion of its component parts affect the degree of moisture. The forester can do much, either to preserve moisture in the soil by excluding or reducing the agencies which dissipate it, or, if there is excess of moisture, by accelerating its consumption, and by draining.

The absolute quantity of moisture required annually by each species is still under investigation, but experience has shown that a fresh soil with, as far as practicable, an even and constant degree of moisture suits most of the species

enumerated above. For the rest, they may be classified as follows :—

Most moisture in the soil is required by: Common alder; next to this ash, most poplars and willows.

Moist soil is liked by: Cembran pine, hornbeam, elm, lime, mountain ash, pedunculate oak.

Fresh soil is liked by: Silver fir, spruce, larch, beech, sessile oak, Norway maple, sycamore, Weymouth pine, sweet chestnut.

On dry soil thrive: Corsican pine, Scotch pine, Austrian pine, birch, Robinia and aspen.

d. A suitable Chemical Composition.

Apart from water and gases, the soil consists of mineral and organic substances. These affect the development of the trees, partly by providing nourishment, and partly by determining the physical properties of the soil. Woody plants take the greater portion of their nourishment from the air, more especially carbon, but a certain portion, including the mineral substances, is derived from the soil. Hence, it is of importance to ascertain the actual quantities of such substances in the plant. The contents of mineral substances vary in different parts of the tree; thus wood taken from the stem generally contains less than 1 per cent. of ashes (according to weight), branches and twigs about 2 per cent., bark 2—3 per cent., and leaves and needles from 4—6 per cent. Ebermayer* gives the quantities, as shown in the table on page 40, of the more important substances, which an average crop takes from the soil, per acre and year.

The data of this table justify the following conclusions :—

(1.) The substances required by forest trees are, qualitatively, the same as those required by field crops.

(2.) Beech high forest requires, for the production of leaves and wood, nearly as much mineral substances as an average

* Physiologische Chemie der Pflanzen, Volume I., page 761.

field crop; it requires more lime, but much less of the rarer substances, such as potash and phosphoric acid.

(3.) Conifers require smaller quantities, especially Scotch pine, which is satisfied with about one-fourth of those wanted by beech.

TABLE SHOWING THE PRINCIPAL MINERAL SUBSTANCES TAKEN ANNUALLY BY VARIOUS FIELD AND FOREST CROPS FROM AN ACRE OF LAND.

Description of Crop.	Total Quantity of Ashes.	K_2O.	CaO.	MgO.	P_2O_5.	SO_3.	SiO_2.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Field Crops:							
Rye, wheat, barley, oats	186	28	14	9	21	4	100
Leguminous Crops, various . . .	173	44	44	11	27	9	9
Colza	199	52	39	14	43	27	9
Clover (hay) . .	303	98	107	27	36	11	9
Potatoes . . .	231	107	36	18	32	14	8
Beet	320	164	36	24	28	11	14
Meadow Hay . .	294	71	44	18	27	11	107
Tobacco . . .	214	55	27	13	16	12	75
Wine	199	84	41	15	24	...	...
Average . .	235	78	43	17	28	11	37
Crops of Trees, wood and leaves:							
Beech, high forest .	194	13	89	15	12	4	56
Silver fir " .	123	16	75	10	10	4	8
Spruce " .	138	8	62	8	7	3	45
Scotch pine " .	52	6	24	5	4	2	6
Average . .	126	11	62	10	8	3	29
Crops of Trees, wood only:							
Beech, high forest .	27	5	13	3·7	2·3	0·3	2·7
Oak " " .	24	2·7	18·7	0·9	0·9	0·2	0·4
Silver fir " .	17	6	4	3	1·8	0·9	0·9
Spruce " .	20	4	9	2	1·3	0·6	4
Scotch pine " .	13	2	8	1	0·9	0·2	0·4
Birch, high forest .	12	2	4	2	1·2	0·1	0·9
Average . .	19	4	9	2	1·4	0·4	1·6

(4.) For the production of wood alone (excluding the leaves), forest trees require much smaller quantities than field crops. Thus, beech takes only one-ninth, Scotch pine about $\frac{1}{18}$th, and the six species enumerated on an average about $\frac{1}{12}$th of the quantity required by field crops. Of the rarer substances

potash and phosphoric acid, trees take, on an average, only about $\frac{1}{20}$th of the quantity necessary for field crops.

(5.) Almost any soil can furnish a sufficient quantity of mineral substances for the production of a crop of trees, provided the leaf mould (humus) is not removed, and good soils will continue to do so, even if a certain portion of the humus is taken away. If, however, the removal of litter is carried on annually and for a long period, any but really fertile soils are likely to become exhausted, just as lands, on which field crops are grown, cannot as a rule go on for ever without manuring.

(6.) Poor soils, which are not capable of producing a crop of broad-leaved trees, may yet be able to yield a fair return if planted with less exacting conifers, especially Scotch and other pines.

The above conclusions agree with the results of practical experience. It has been found that the quantity of wood production is not directly proportionate to the quantity of mineral nourishing substances in the soil. Again, woods thrive equally well on soils of the most different geological origin, while great differences exist in the development of one and the same species if grown on soils of the same geological origin. These phenomena are explained by the great importance of the physical properties of the soil, depth, porosity and a proper degree of moisture. To ensure a favourable condition of the physical properties, should, therefore, be the forester's chief aim, and this he can do best by preserving the humus, especially on middling and poor soils. Humus increases the depth of the soil, absorbs from the atmosphere considerable quantities of aqueous vapour, carbon dioxide and ammonia; according to Henri, it takes nitrogen direct from the air; it is capable of holding a large quantity of water, which it gradually gives up to the lower layers of the soil; it loosens too firm a soil, and gives somewhat more consistency to a soil which by itself is too porous; finally, it moderates the extremes of cold and heat. The poorer a soil, the more

important is the preservation of the humus. At the same time, too large an accumulation of humus is likely to lead to an excess of humic acid, followed by a deterioration of the soil and the formation of a pan. To avoid this, the forester must tend his woods so that the decomposition of the humus proceeds at the most favourable rate.

e. Summary.

Summarising all the demands which forest trees make on the soil, it may be said that all species like a soil which is minerally rich, deep, porous, fresh, warm and rich in humus, such as a mild loam with a good layer of humus. Some species find the necessary conditions more on one class of soil than on another; for instance, oak, beech, ash, elm, maple, and Austrian pine like a certain quantity of lime in the soil, probably less on account of its chemical composition than of the physical qualities which an admixture of lime produces. Most coniferous trees, on the other hand, are more frequently found on loamy and sandy soils.

Though all trees like a good fertile soil, the several species differ considerably as to the minimum of fertility on which they can thrive; that is to say, some are more exacting in their demands than others. In this respect the following scale is suggested:—

Least exacting are: Austrian pine, Scotch pine, Corsican pine, birch, poplars, tree willows, mountain ash, Robinia, mountain pine and alder.

Moderately exacting are: Weymouth pine, spruce, Cembran pine, larch, lime, osiers, horse chestnut, hazel, hornbeam, Norway maple and Douglas fir.

Most exacting are: Silver fir, beech, sweet chestnut, sessile oak, sycamore, ash, elm and pedunculate oak.

It will be observed that the valuable broad-leaved species are, on the whole, more exacting than the soft broad-leaved species and the conifers.

Any classification like that given above must, however, be received with some caution; its object is merely to give a

general idea of the subject. In practice, deviations occur constantly, according to the local conditions under which the trees grow.

SECTION IV.—EFFECT OF FOREST VEGETATION ON THE LOCALITY.

It has been shown in the previous sections that the condition of the locality governs the growth of forest trees. It is now necessary to consider the effect of forest vegetation on the locality, more especially on two of its factors—humus and moisture. This effect is produced chiefly by the following two agencies:—

(1.) The protection which growing woods afford to the soil and adjoining layers of air.

(2.) The humus which is formed by the fall of the leaves, branches, twigs, flowers, fruits, etc., and by certain plants growing under the shelter of trees.

In well stocked woods, the crowns of the trees form a thick leaf canopy, or complete cover overhead. If the trees are all of the same age and height, the leaf canopy is at a uniform height above the ground, that height being at first small, but increasing with age. In woods of uneven age, the cover is of a somewhat different nature; it consists of groups of crowns at varying distances from the ground. In either case, the cover overhead protects the soil and adjoining layers of air against sun and wind; in even aged woods more against sun, and in uneven aged woods more against wind.

Again, the trees shed their leaves, flowers, fruits, and even branchlets, while mosses and other plants, which thrive under the shelter of the leaf canopy, die; thus a layer of humus on the soil is formed. Finally the roots of the trees penetrate into the soil and keep it together.

The shelter from above, the humus on the soil, and the roots of the trees together produce certain effects, which may be summarised as follows:—

(1.) The temperature of the soil and the adjoining air is lowered during the day and raised during the night;

hence, the extremes of temperature are moderated, and the climate rendered more equable.

(2.) The mean temperature of the soil and the adjoining air is lowered. The reduction is greatest in summer, next in spring, next in autumn, and it is slight in winter; it is also greater in the soil than in the adjoining air.

(3.) The relative humidity of the air is increased, and the evaporation from the upper layer of the soil reduced.

(4.) A favourable degree of moisture in the upper layer of the soil is maintained, provided the total amount of precipitation does not sink below a certain minimum; if the latter is the case, the level of ground water in the soil may be lowered by a crop of forest vegetation.

(5.) Noxious forest weeds are kept in check.

(6.) A steady and suitable progress in the decomposition of the humus is ensured, whereby the physical qualities of the soil are improved, or at any rate maintained.

(7.) An additional supply of organic and nitrogenous matter, taken by the plants from the atmosphere and brought into the soil by the falling leaves, flowers, fruits, and twigs, decaying mosses and other plants, is procured.

(8.) The soil is protected against the mechanical action of water and air currents, thus preventing or reducing denudation.

To produce these effects in a high degree, it is necessary that the leaf canopy should be dense, so that it not only keeps out sun and air currents, but also yields a heavy fall of leaves for the production of humus. Only certain species of forest trees possess these two qualifications. During youth, most species answer, no doubt, very well; with advancing age, however, the crowns are not only lifted higher and higher from the ground, but most species thin out considerably. The result is that the leaf canopy becomes more and more

interrupted and thinner, followed by a crop of noxious weeds too rapid decomposition of the humus, accelerated evaporation of the moisture from the upper layer of the soil, and generally a reduction of the fertility of the soil. To prevent such results, the forester must either cut over the woods before the process of thinning out has proceeded too far, or underplant such woods, or cultivate species which are capable of maintaining a complete cover overhead up to an advanced age.

Amongst the timber trees, with which this book deals, beech, silver fir, spruce, Douglas fir, and hornbeam are the species which, above all others, preserve a complete leaf canopy until, or nearly to, maturity. These are shade bearing species. All other species are, with certain modifications, less capable of preserving the factors of the locality; the greater their light requirement and the thinner their crowns, the smaller is their capacity in this respect. Those least suitable are birch, poplars and Robinia; next willows, larch, most pines (with advancing age), oak, ash, elm, Norway maple, sycamore and alder.

The production of humus from fallen leaves is greater in woods consisting of broad-leaved species than in coniferous woods, because the important broad-leaved species are deciduous, and shed the whole of their foliage every year, while, with the exception of larch, the conifers are evergreen. The silver fir sheds about one-ninth of its foliage annually, spruce about one-seventh, the pines about one-third to one-fourth. The production of humus from fallen leaves is, generally speaking, greatest when the rate of height growth culminates.

The accumulation of humus depends greatly on the rapidity with which the leaves are decomposed, a process which is regulated by the species, degree of cover overhead, and the character of the locality. Generally speaking, needles decompose more slowly than leaves. Of needles, those of the larch decompose most quickly, next perhaps

those of Weymouth pine, Scotch pine, and Austrian pine, last those of silver fir and spruce. Of leaves, those of ash, alder, hornbeam, lime, and hazel decompose quickly; more slowly the leaves of oak, birch, and sweet chestnut. The leaves of beech stand perhaps half-way, but as beech woods enjoy a dense shade, their accumulation of humus is much greater than that found in oak or birch woods. On calcareous and sandy soils, humus decomposes more quickly than on loam and clay soils. It is also more rapid in warm low lands than in cloudy mountain regions. The most suitable, or normal, time for the process may be put at two to three years, when the most favourable results in respect of quantity and quality of humus are produced.

A few words about each of the more important species will not be out of place here :—

Beech improves the soil in the highest degree, because it has a dense crown and yields a heavy crop of leaves, which decay slowly. Beech woods, if undisturbed, show a thicker layer of humus than woods of any other species.

Hornbeam approaches beech in this respect, though it does not equal it.

Lime gives good shade and a heavy crop of leaves, but its timber is of such inferior quality that it is rarely planted for economic purposes.

Sweet chestnut sheds a heavy crop of leaves, but the leaf canopy is comparatively incomplete, admitting too much sun.

Oak, ash and *willow* have too thin a leaf canopy to do justice, generally speaking, to the locality.

Silver fir and *spruce* are capable of preserving a dense cover overhead up to an advanced age. Douglas fir stands near them in this respect.

Evergreen conifers, other than silver fir, spruce, and Douglas fir, though they may not possess a dense leaf canopy, are often capable of preserving the fertility of the soil for a certain period, because under their half shade mosses grow, which protect the soil just as well as a thick layer of leaves.

When these conifers begin to thin out to some extent, the mosses disappear gradually, except in very moist localities; hence, these species should not by themselves be treated under a high rotation, except on fertile soils. Of the conifers which are here referred to, Weymouth pine, Austrian pine, Cembran pine, and mountain pine have a fairly dense leaf canopy, and yield a considerable crop of needles, more especially Weymouth pine. Scotch pine has a thinner crown, and a tendency to open out after the age of thirty or forty years, when the moss is liable to disappear and to be replaced by a crop of grass or heather. At the same time, the density of the leaf canopy of this tree differs very considerably according to the conditions under which it is grown. The Scotch pine grown in the moist climate of the British Isles gives a much denser cover than when grown in dry continental climates.

Larch provides but a thin leaf canopy in summer, and is leafless in winter. It begins to thin out at an early age; the moss disappears quickly, is replaced by grass, and the needles decay rapidly, so that the tree is unfit for preserving the fertility of the soil.

The power of preserving the factors of the locality which is peculiar to the several species, governs their adaptability to be raised in pure woods, a subject which will be dealt with further on.

SECTION V.—ASSESSMENT OF THE QUALITY OF THE LOCALITY.

It is the duty of the forester to determine, in the case of any particular locality, which species is best adapted for cultivation, so as to realise the objects of the proprietor. In order to attend to this duty successfully, means must be provided by which the *quality*, or *yield capacity*, of the locality can be readily ascertained. Various methods have been proposed for this purpose, of which the following two will be shortly considered here:—

(1.) Assessment according to the several factors of the locality.

(2.) Assessment according to a crop of trees already produced on or near the locality.

Whenever the second method is possible, it should be followed; only in the absence of a forest crop should the first method be adopted.

A third method may be mentioned. It has been proposed to assess the quality of the locality according to the natural appearance of certain plants, which would depend either on the presence in the soil of certain substances, or on certain other conditions. Though this holds good to some extent, the method of assessment by itself is without practical value in silviculture, but it may be used as an auxiliary of the methods now to be described.

1. Assessment of the Locality according to its Several Factors.

The factors of the locality naturally arrange themselves into two groups, those of the climate and those of the soil and subsoil.

As regards climate, it is necessary to ascertain:

(*a.*) The geographical position of the locality, that is to say, the latitude, and in some cases, the longitude.

(*b.*) The local peculiarities of the locality, such as altitude, aspect, slope, surroundings, temperature, moisture in the air, rainfall, exposure to strong, cold or dry winds, susceptibility to late or early frosts, etc.

All these matters have been dealt with in a previous section.

Turning to the soil, the following points, as already indicated, require attention:—

(*a.*) The depth of the soil.

(*b.*) The degree of porosity.

(*c.*) The degree of moisture peculiar to the soil.

(*d.*) The chemical composition.

A detailed examination of the factors of the soil is a complicated and difficult operation, which it is not intended to

describe here. There is, however, a somewhat rough and ready method, which generally suffices for silvicultural purposes, and which will be shortly indicated.

The most convenient way of examining the soil is to dig holes, if possible in spots which promise to yield average results. On fairly level ground, a spot should be selected on an average part of the area, that is to say, neither in any small depression nor on any slight elevation which may exist. In hilly or mountainous localities, separate holes must be dug on the ridge, the slope and at the bottom of the valley. The depth of the hole must be at least equal to the depth to which the roots ordinarily penetrate, that is to say, 3 to 4 feet. Where rock is met at a smaller depth than this, its stratification and general composition should be ascertained, as well as its effect upon the regulation of moisture and the stability of the trees. One side of the hole, at any rate, should be perpendicular, so that the thickness of the successive layers of the soil can be measured, in so far as they are indicated by different colour, different degree of cohesion, and other outward signs. The depth to which the soil is coloured dark by humus should be specially noted.

This operation will show, whether the soil is sufficiently deep to admit of a proper spreading of the roots, and if not, the examination of the subsoil will indicate, how far the latter can make up for the shallowness of the surface soil. The same operation will indicate, what effect the depth and nature of the soil have on the degree of moisture. Next, the degree of division, or the nature of the grain of the soil, must be ascertained. This can be done by shaking a sample, if necessary of each successive layer, with about three times its volume of water in a graduated tube, until all parts are thoroughly separated; the tube is then placed in a vertical position and watched. As coarse grains settle more quickly than fine grains, it follows that the time occupied compared with the thickness of the deposit indicates the degree of division of the particles. A high degree of division indicates a stiff soil, the

presence of coarse grains the reverse, and thus an idea can be formed of the degree of porosity.

If necessary, the capacity to absorb water, to attract it from the subsoil, to retain it, and the hygroscopicity of the soil can be ascertained by special experiments, but in practical silviculture they are rarely called for.

The exact composition of the soil can be ascertained only by means of a chemical analysis. In practice, the forester can easily acquire the faculty of distinguishing in a rough and ready manner between the several constituents. He recognises :—*Clay* by a high degree of cohesion, a fatty feeling, active absorption of water while emitting a clayey smell, slow disintegration in water, slow drying followed by cracking, frequently a grey colour, etc.; *loam* by a lesser degree of cohesion than in the case of clay, rougher feeling, quicker disintegration in water, and generally a more reddish colour; *lime* by active effervescence if treated with an acid, porosity, light whitish to greyish-white colour, which is, however, frequently turned red by iron, a rough but fine grained feeling, etc.; *sand* by very slight cohesion, or hard grainy feeling, immediate disintegration in water and rapid settling down in it, a light, glossy, shiny, yellowish-white colour, often converted into red by iron, into white by lime, into black by humus; *humus* by its porosity and light weight, peculiar smell like that of fresh garden earth, rapid disintegration in water, which remains dark coloured for a long time, blackish colour which disappears on roasting; *iron* by red colouring, etc.

In order to recognise more easily the principal constituents of a soil and their proportion, a sample may be mixed in a glass tube with about twice its volume of water, well stirred until completely dissolved, and then allowed to settle. At the bottom of the glass tube the following deposits will be observed, beginning with the lowest :—

First: The rougher grains of sand.

Second: The finer grains of sand.

Third: Lime, chalk, and the coarser clay.

Fourth: The finer clay and particles of humus.

The thickness of the layers indicates the proportion of each substance.

In spite of the most persevering attempts, experience has shown that the assessment of the locality in the manner indicated above is always subject to grave errors, because the various factors may compensate each other, replace one another, or may be altogether unassessable. To make matters worse, the factors are rarely the same over extensive areas, but change from one spot to another. On the whole, the method which has just been indicated can only serve as a makeshift when no better means of assessment are available, or as a help in the application of the method now to be described.

2. Assessment of the Locality according to a Crop of Trees produced by it.

When a locality has already produced a crop of trees, it may be assumed that, unless extraordinary events or irregular treatment have interfered with the development of the trees, the effects of all its factors have found due expression in such crop, which is therefore the best guide for the assessment of the quality, or yield capacity, of the locality. If, for instance, an acre of ground has produced a total quantity of 5,000 cubic feet of wood in the course of 100 years, the quality, or annual yield capacity, is represented by $\frac{5000}{100} = 50$ cubic feet, in other words, by the mean annual production.

The applicability of this method depends principally on the following three conditions:—

(*a*.) That the existing wood has grown up under normal conditions; in other words, that no extraordinary disturbing events have occurred which affected the health and development of the crop, as, for instance, damage by cattle or deer, insects, fire, theft, removal of litter, faulty treatment, etc.

(*b*.) That the factors of the locality have not undergone any decided change, either for the better or worse, during the production of the crop; for instance, the stock of humus or the degree of moisture may have been affected by external interference.

(*c*.) That the existing crop is of a sufficient age to make sure that the factors of the locality have found full expression in the same, since a wood may thrive well up to a certain age and then fall off considerably.

Whenever these conditions exist to a fair extent, the method of assessment is the best which is at the forester's disposal; and in its application he need not restrict himself to a crop actually growing on the area, but may be guided by one growing on a neighbouring piece of land, provided the general conditions are about the same in both cases.

A great quantity of data bearing on the yield capacity of land under forest has, in the course of time, been collected and brought together in so-called "*Yield Tables*," that is to say, tables which indicate the yield which an acre of land may reasonably be expected to give according to quality.

The details regarding yield tables will be found in Volume III. of this Manual. By way of illustration the following data may be given:—

TOTAL PRODUCTION OF TIMBER AND FIREWOOD IN THE COURSE OF ONE HUNDRED YEARS, IN SOLID CUBIC FEET PER ACRE.

Species of Tree.	Total Production on the			
	I., or Best Quality.	II., or Medium Quality.	III., or Lowest Quality.	
Silver fir	23,900	16,500	10,700	Data derived from numerous and reliable measurements.
Spruce	22,200	14,000	7,200	
Beech	15,200	9,300	4,700	
Scotch pine	13,500	8,500	3,500	
Oak grown on alluvial soil	12,700	9,400	6,200	
Larch	12,100	6,800	1,800	Data somewhat less reliable.
Alder	9,100	5,400	1,700	
Birch	7,900	4,300	1,100	

The quantities given for the first quality are the highest which can be produced, and they are comparable for the several species; the same may fairly be said regarding the figures given for the second, or medium, quality. The quantities given for the third, or lowest, quality are less comparable, because the lowest limit suitable for the several species differs considerably. Of our more common forest trees, silver fir produces the greatest quantities, and spruce comes near it. As regards oak, it should be noted that the figures refer to woods grown on alluvial soil only; there are as yet no data available for oak grown on other lands.

Taking Scotch pine as an example, it may be said that, if a locality stocked with it has produced 13,500 cubic feet of woody matter in the course of 100 years, that locality is of the first, or best, quality or yield capacity; if it has produced 8,500 cubic feet, it is of a medium quality; and if the production amounts to only 3,500 cubic feet, the quality is of the lowest, on which that species is ordinarily grown.

The quantities given above include all thinnings taken out of the woods in the course of the 100 years.

Of exotic species, it may be said that Douglas fir and Sitka spruce are likely to yield higher quantities than silver fir and Norway spruce respectively. As regards other exotic trees, the experience is as yet limited.

CHAPTER II.

DEVELOPMENT OF FOREST TREES.

In dealing with the shape and development of forest trees, it is assumed that the student has already acquired a botanical knowledge of the several species, so that here only their silvicultural characteristics need be described, more especially the shape peculiar to each species, the height, diameter and volume growth, lease of life, and reproductive power.

1. Shape.

Different species of trees naturally develop different shapes. Some species, like spruce, silver fir and larch, have a decided tendency to form a strong stem in preference to the development of the crown. Others, like oak, lime and sweet chestnut, develop their crown in preference to the stem. Some species are frequently forked, as ash, Robinia, and also elm. Cembran pine often shows a candelabra-like shape, especially in stony localities. The actual shape depends, however, on a variety of influences, amongst which the following may be mentioned :—

a. Growing Space.

The individual character of a tree can be best recognised if it has grown up in a free position, so that its natural development has not been interfered with. When trees have been reared in this way, their shapes can be classified as follows :—

An undivided stem throughout have : Spruce, silver fir, larch, Douglas fir, also Weymouth pine.

Divided in the upper part only are : Scotch pine, alder, beech, black poplar, Cembran pine.

Divided somewhat lower down are: Ash, Norway maple, sycamore, elm, sessile oak, sweet chestnut.

Decidedly branching with a divided stem comparatively low down: Pedunculate oak, lime, hornbeam, mountain pine.

The shape is considerably altered when the trees are grown in crowded woods, where each enjoys only a limited growing space. In that case all species have a greater tendency to the development of stem than of crown, and this is in the same proportion as the species is light demanding and the growing space reduced. Thus, the crown of the silver fir covers often the whole of the upper half of the tree, that of spruce the upper third (and generally a little more), also that of beech and hornbeam; the crown of larch, Scotch pine, oak, birch and aspen is reduced to the uppermost part of the stem. The effect is that the more elevated the crown, the nearer will the shape of the bole approach that of a cylinder, and consequently the more valuable it will be.

b. Age.

All species, when grown in crowded woods, develop during the early part of life a conically shaped crown, but when they approach their full height the crowns differ considerably, so that the following classification applies:—

A conical crown with thin branches have: Spruce, silver fir, Douglas fir, larch.

An egg-shaped crown have: Elm, beech, Norway maple, sycamore, birch, sessile oak.

An inverted broom shape horizontally extended, with strong branches have: Pedunculate oak, sweet chestnut, black poplar, lime.

After the height growth has been completed, the crowns of trees become flat or rounded off, more or less extending in breadth. Only spruce makes an exception, as the leading shoot continues to grow up to a great age, though very slowly.

The practical conclusion to be drawn from these peculiarities

is that only shade bearing species, which are satisfied with a limited growing space, are capable of preserving a complete cover up to an advanced age, such as beech, silver fir, spruce, Douglas fir, and also hornbeam. Much inferior in this respect are ash, Scotch pine and larch, chiefly because they are light demanding; also maple and sycamore. If to the demand for light is added a strong tendency to develop branches, then the interruption of the cover occurs early, as in the case of oak (especially pedunculate) and sweet chestnut. This tendency is the more pronounced, the less suited the locality is for the species.

c. Soil.

The nature of the soil influences the shape of the trees in the case of all species. Fresh, deep, fertile soils encourage height growth. Shallow, rocky soils produce only short stems with a tendency to divide the stem and develop branches.

d. Situation.

The development of stem decreases and that of branches increases in the same degree as the species is removed from its optimum. At great elevations, the shape is reduced to that of a shrub or bush. Similar phenomena are observed on proceeding north, and in localities exposed to cold winds. Trees exposed to continuous strong winds, as near the sea coast, assume often a one-sided shape.

2. Height Growth.

The energy of height growth differs not only according to species, but is also subject to considerable modifications in the case of one and the same species, according to the age of the tree, the locality, method of formation and the treatment.

a. Species.

Amongst the trees here under consideration, spruce, silver fir, larch and Weymouth pine attain the *greatest height*; they

ordinarily reach a height of 120 feet, and under favourable conditions, much more. Douglas fir in Vancouver Island reaches a height of 300 feet, and it is likely to reach in Western Europe a greater height than the indigenous trees.

Next come: Beech, Scotch pine, Corsican pine, oak, ash, lime, elm, Norway maple, sycamore; then poplar and birch. These species do not, except under specially favourable conditions, exceed a height of 110 feet.

Beech reaches in Normandy a height of 170 feet; oak one of 150 feet, but these are exceptional heights.

Next come: Austrian pine, Cembran pine, hornbeam, alder, willow. They do not, as a rule, exceed 75 feet in height.

b. Age.

The energy of height growth during the first part of life is of special importance in silviculture. Generally, the light demanding species are at this time faster growing than the shade bearing species. Assuming favourable conditions of growth as found in the natural home of each species, they may during youth be arranged as follows, commencing with the fastest growing kind :—

Birch, larch.
Aspen, alder, Norway maple, sycamore, ash, lime, elm.
Douglas fir, Weymouth pine.
Scotch pine.
Austrian pine.
Sweet chestnut.
Beech, oak.
Hornbeam.
Spruce, Cembran pine.
Silver fir.
Yew.

As soon as the first youth, say up to 20 or 30 years, has been passed, a considerable change occurs. Some species, like larch, and under favourable circumstances also Douglas fir, Weymouth pine, Scotch pine and birch, preserve their

fast growth until they have completed their principal height growth.

Others, like Cembran pine and hornbeam, remain slow height growers throughout life. The majority of species, however, increase their rate of height growth considerably, and this is especially pronounced in spruce, silver fir, also beech and oak, so that they soon reach and surpass trees like

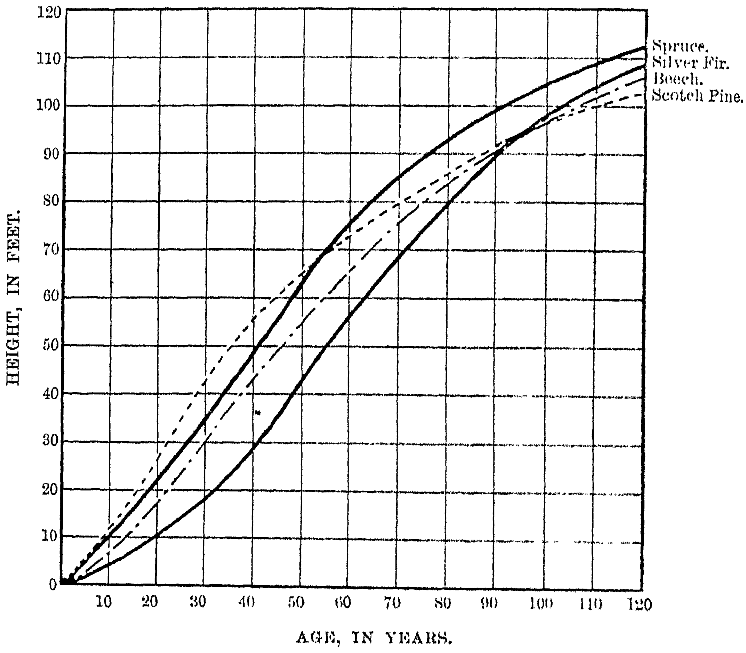

Fig. 1.—Diagram illustrating the Relative *Height* Growth of Spruce, Silver Fir, Beech, and Scotch Pine on Localities of the First Quality.

ash, Norway maple, sycamore, aspen, which do not grow at the same rate.

The duration of height growth in the more advanced periods of age is greatest in those species in which the development of stem naturally predominates over that of the crown, such as spruce, silver fir, larch, Douglas fir, and Weymouth pine, and these species reach ultimately the greatest height.

Among broad-leaved species, sessile oak, elm and beech preserve their height growth longest. In the case of the other broad-leaved species, the crown is rounded off at an earlier period, when height growth practically ceases.

c. Locality.

The factors of the locality have a decided effect upon height growth. It has already been pointed out that deep, fresh, fertile soils produce much higher trees than shallow, dry, rocky soils. Elevation exercises also a considerable influence. It may be said that every species shows its greatest height growth at that elevation which offers the most favourable climatic conditions for its growth; above that elevation the height growth decreases, and in many cases also below it. In situations exposed to strong air currents and other unfavourable influences, height growth is comparatively small.

d. Methods of Formation and of Treatment.

They affect the height growth principally on account of their effect upon the establishment and preservation of a complete leaf canopy. The more complete the cover, the better will be the effect upon the height growth of most broad-leaved species, Scotch and other pines; it is less pronounced in the case of silver fir, spruce and larch. In this respect the manner in which thinnings are conducted is of paramount importance, a subject which is dealt with in Part III. of this volume.

3. Diameter Growth.

Generally speaking, the increase of the diameter of the stem (or bole) is, in the case of all species, fairly proportionate to the height growth, that is to say, both height and diameter growth are greatest at the same period of life. In the case of light demanding species, the diameter increment often reaches its maximum between the 20th and 30th year of age, a good increment being maintained up to

the 50th or 60th year, when it commences to fall off. Shade bearing species and oak reach the maximum diameter increment later on, but it is also longer maintained, often up to the 90th year, before it commences falling off to any considerable extent.

Apart from species, the diameter increment depends on—

(*a.*) The quality of the locality.

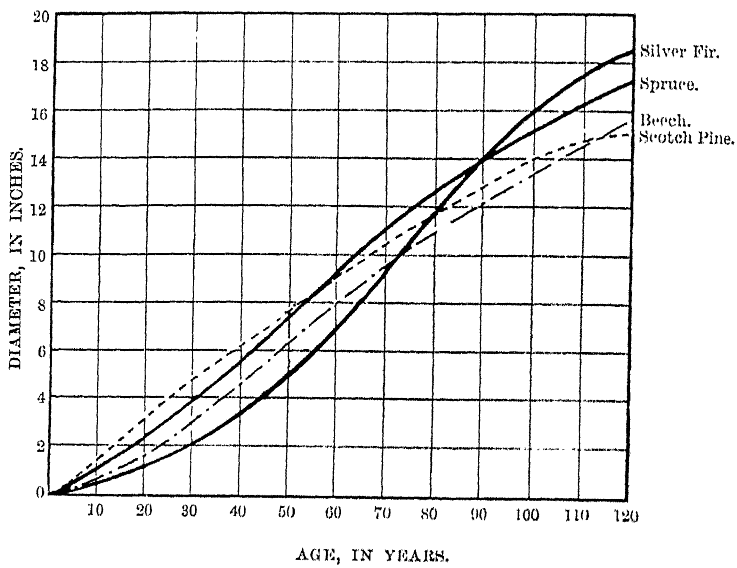

Fig. 2.—Diagram illustrating the *Diameter* Growth of Silver Fir, Spruce, Beech, and Scotch Pine, on Localities of the First Quality.

(*b.*) The amount of light which the tree receives and can utilize; in other words, the extent of the crown, which is governed by the growing space.

Limited space in a crowded wood reduces the diameter increment, a free position increases it; hence, height growth and diameter growth frequently demand opposite conditions. It is the business of the forester to give the most profitable growing space; in other words, to give to the individual trees from time to time sufficient room to en-

courage diameter growth, without endangering the progress of the height growth.

The effects of a great surface of foliage and unimpeded enjoyment of light are very remarkable, when healthy trees, which have been raised in a crowded wood, are gradually given more growing space. Such an opening out can, provided the period of height growth has not come to an end, produce a revival of the diameter increment, after its first maximum has been passed, due to an increased leaf surface, or to a greater intensity of action, even if the leaf canopy is not materially extended. This revival of diameter growth generally lasts for a number of years, differing according to species and quality of locality; then it gradually dies away again. Nor does a tree profit by an excessively large leaf-surface, because there is a limit, beyond which a tree cannot assimilate and convert into wood the nourishing elements available to it.

Where both great height and diameter growth are wanted, it is best to keep the wood fully stocked during youth, and to give only a moderate growing space to each tree until towards the end of the principal height growth, when the growing space of each remaining tree should gradually be increased, so as to develop more extended crowns and greater diameter growth. This is only possible while height growth is still going on; once that has stopped, the thinning out will not be followed by any appreciable extension of the crowns, which can only be produced by transferring to it the energy of height growth. The possibility of such a transfer is longest preserved in silver fir, spruce, oak, and beech.

4. Volume Growth.

The increase in volume depends on both height and diameter growth, and that method of treatment, which promotes each in due proportion, must ultimately yield the largest volume; in other words, woods should be neither too crowded, nor too open. In the one case thin tall trees, and in

the other short thick trees would be produced. The most favourable density of the crop can only be ascertained by accurate statistics. Experience has shown that the greatest volume is ultimately obtained, if the woods are moderately heavily thinned from their youth onward, but this interferes often seriously with the quality of the timber.

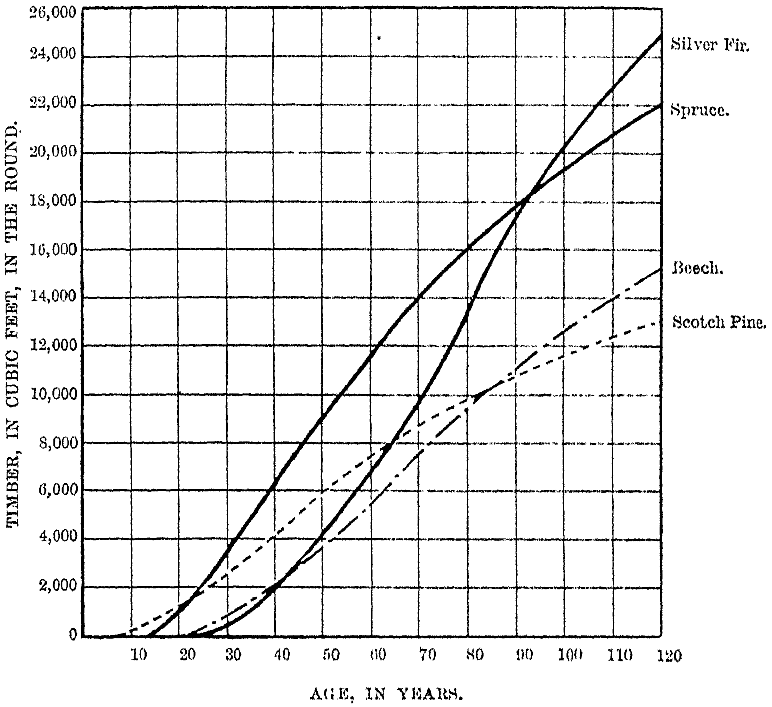

Fig. 3.—Diagram illustrating the *Production of Timber* per Acre, on Localities of the First Quality, by Spruce, Beech, Scotch Pine, and Silver Fir.

Apart from these general considerations, a great difference exists in the volume produced by the several species when grown in regular woods; in this respect, some of the more important kinds may, according to the latest investigation, be arranged in the following manner, commencing with that species which produces the greatest average increment, *calculated for a prolonged space of time.*

Douglas fir, silver fir, spruce, Weymouth pine, larch, beech, Scotch pine, oak, ash, birch.

On the whole, conifers produce much larger volumes than broad-leaved species. The diagram on p. 62 will illustrate this.

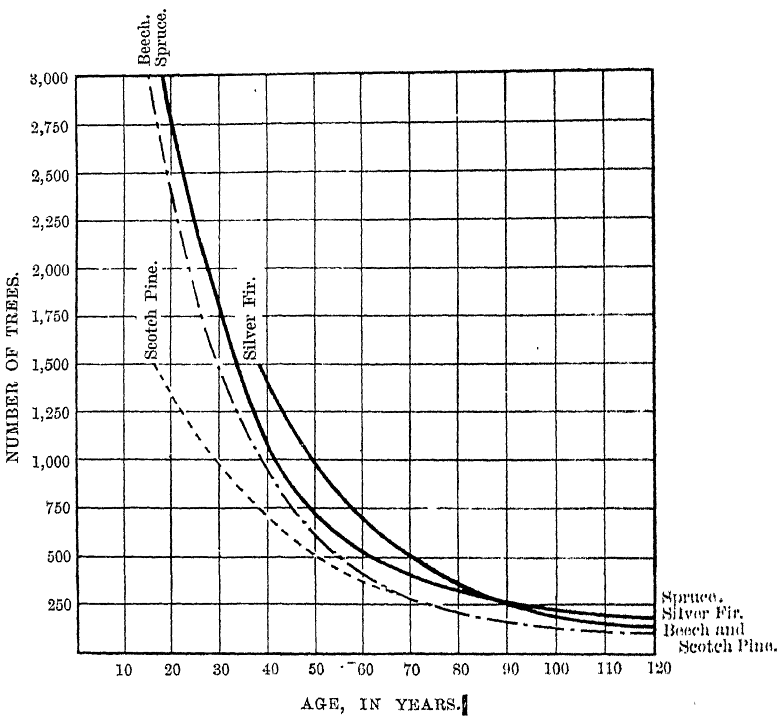

Fig. 4.—Diagram illustrating the *Number* of Trees per Acre at Various Ages, and on Localities of the First Quality, of Spruce, Silver Fir, Beech, and Scotch Pine.

The increment laid on by an individual tree does not by itself govern the increment produced per acre, because the latter is represented by the increment per tree multiplied by the number of trees per acre. For instance, if an acre of ground can hold 100 mature silver firs, each of which has a volume of 100 cubic feet, the total volume per acre will be 10,000 cubic feet; if an acre can hold 50 mature oak trees,

each with a volume of 150 cubic feet, the total volume per acre will be only 7,500 cubic feet, or 2,500 cubic feet less than in the case of silver fir.

The number of trees which find room on an acre of ground depends chiefly on :—

(*a.*) The light requirement of the species.

(*b.*) The tendency of the species to develop the crown in preference to the stem.

(*c.*) The quality of the locality.

Hence, an acre stocked with the light-demanding birch, ash, or spreading oak, contains a smaller number of trees and a smaller volume than an acre stocked with beech. Again, larch and Scotch pine woods contain fewer trees and a smaller volume per acre than silver fir and spruce woods. The number of trees per acre on a fertile soil is considerably smaller than on an inferior soil.

Full details on this question will be found in Volume III. of this Manual. In the meantime, the accompanying diagram (p. 63) will give a general idea of the number of trees found on localities of the first quality in the case of spruce, silver fir, beech, and Scotch pine.

5. Duration of Life.

A great difference exists in the age which the various species attain ultimately. If grown under conditions which are in harmony with their requirements, the yew lives for more than 1,000 years, the oak comes often near that age, if it does not exceed it; lime, elm and sweet chestnut reach and surpass an age of 500 years; beech reaches a similar age under favourable circumstances, but ordinarily both beech and silver fir die before that age. A limit of 300 years may be assigned to ash, maple, sycamore, spruce, larch, Scotch pine and hornbeam; while aspen, birch, alder and willow live, under ordinary conditions, little beyond 100 years.

In forestry, the trees are, as a rule, cut over long before they have reached the natural limit of their life. Nevertheless,

many cases occur, where trees have been grown under conditions which are not quite in harmony with their requirements, so that they die, or at any rate fall off in health and growth long before they would, in the ordinary course, be cut over; hence it is of importance to consider the conditions under which the growth continues to be healthy to an advanced age.

In the first place, the nourishing organs, crown and roots, must be able to develop normally in accordance with the requirements of the tree at the different periods of life; in other words, they must be given at all times the required growing space, without, however, checking their height growth or interrupting the cover overhead for a lengthy period of time. Unless a tree is provided with a sufficient quantity of organs, it will not be able to overcome successfully internal and external damage which endangers its life. The power of resistance in this respect differs considerably in the various species. It is great in oak, hornbeam, lime, willow, elm, yew and Cembran pine, but small in alder, Norway maple, sycamore, beech, spruce.

The second condition of longevity is, that the locality should offer to the tree all it requires for a proper development. On the whole, it may be assumed that, where a tree is indigenous, it finds all it requires (though this is not without exceptions). Localities with different factors are liable to be unsuited to the species, either from offering too little or too much in respect of temperature and moisture, or insufficient nutriment and depth in the soil, etc. Either case may be injurious to the development of the tree, and especially to the quality of the timber produced. For instance, spruce is naturally fond of a cool climate; by transferring it to the dry and warm air of the low lands it generally grows much more quickly, but does not yield the same quality of timber, is shorter lived, and subject to more dangers, than in its mountain home.

Trees raised in fully stocked compact woods do not live as long

as when grown in the open. Moreover, in that case various other important considerations must be taken into account. After having weighed these, the forester decides on the age limit which is most likely to realise the objects of management.

What the objects of management are, has been indicated in the Introduction to this volume. They govern the determination of the *rotation*, or the time which elapses between the formation and final cutting over of a wood. Whatever motives may influence the determination of the rotation from a silvicultural point of view, under the method of natural regeneration it should be so fixed as to admit of a proper regeneration of the wood, whether by seed or coppice shoots; in other words, the wood must be cut over while the reproductive power of the species is in an active condition. For further details regarding the determination of the rotation the reader is referred to Volume III.

6. Reproductive Power.

The tendency to reproduce the species manifests itself throughout Nature; in fact the energy devoted to reproduction is frequently stronger than that bestowed upon the preservation of life. Forest trees, in obedience to this law, produce seed during a considerable part of their life, and in large quantities.

In silviculture, the reproduction of trees and woods is effected in two distinct ways, namely:—

(*a*.) From seed.

(*b*.) From shoots which spring from the stool or the roots, followed, in many cases, by the division of the mother plant.

a. Reproduction from Seed.

This is the more common form of reproduction, and on it depends the regeneration of high forest.

The greater the production of seed, and the better its

quality, the more assured is reproduction; both quantity and quality of the seed depend on the age of the trees, the locality, the available light and the species.

(1.) *Age.*—The first point of interest is the time when the various species commence to produce seed fit to germinate. Apart from single trees here and there, the average period may be placed as follows, in the case of trees grown in regular woods:—

At the age of 25—30 *years:* Mountain pine, birch, white alder, aspen, Robinia.

At the age of 30—40 *years:* Scotch pine, Austrian pine, Weymouth pine, larch, Norway maple, common alder, lime, horse chestnut.

At the age of 40—50 *years:* Hornbeam, elm, ash, sycamore.

At the age of 50—60 *years:* Spruce, sweet chestnut.

At the age of 60—70 *years:* Beech.

At the age of 70—80 *years:* Silver fir, Cembran pine, oak.

The most favourable age for the production of seed is, ordinarily, that when the principal height growth is about to be completed, and when an extension of the crown takes place; in other words, when the individual tree lays on its maximum volume growth.

(2.) *Locality.*—The weather during the year, especially during the time of flowering and of the ripening of the seeds, governs the production or failure of seed. Temperature is of first importance; where that is deficient, the production of seed is seriously endangered. Tree seeds contain a comparatively large proportion of ash, and their production necessitates increased assimilation of substances from the soil; hence, fresh fertile soils produce more and better seed than poor soils. A crop of seed requires also large quantities of starch and nitrogen, the supply of which is, in consequence, much exhausted.

Many species no longer produce seed fit to germinate (or only in small quantities or in exceptionally favourable years)

when they have been cultivated beyond the limits of their natural home, as, for instance, sweet chestnut and English elm in the north of England. Other species are very accommodating in this respect, such as birch and Scotch pine.

(3.) *Light.*—Increased assimilation requires an increased supply of light to the crown.; hence, trees growing in the open or on the edges of woods produce more seed than those hemmed in. Suppressed trees rarely produce seed.

(4.) *Species.*—The power of reproduction from seed differs considerably in the case of different species; it depends on the total quantity of good seed produced during a certain period, or on the annual average. The quantity of seed is governed by two things:—

(*a.*) The average yield of each seed year.

(*b.*) The frequency of seed years.

As regards the average yield per seed year, the species can be arranged into two sections as follows:—

Heavy crops: Beech, oak, spruce, Scotch pine, birch, hornbeam, elm, alder, aspen, willow.

Lighter crops: Ash, maple, sycamore, silver fir, larch.

On the other hand, the species may, as regards frequency of seed years, be arranged as follows:—

Beech seeds only after intervals of six, eight, ten, and even more years.

Oak, spruce, Scotch pine, and alder seed, on an average, every three to five years.

The remaining species seed after shorter intervals, and some do so every year.

Taking both factors into consideration, the species may be arranged into the following scale:—

Best: Birch, aspen, willow, hornbeam.

Next: Scotch pine, spruce, wych elm.

Next: Norway maple, sycamore, silver fir, larch, lime, ash, oak.

Last: Beech.

On the strength of long continued observations in Prussia,

Professor Schwappach has compiled the following data:—
Placing the quantity of seed regarded as a full crop equal to 100,

Birch	gives annually	on an	average	45	per cent.
Hornbeam	,,	,,	,,	42	,,
Common alder	,,	,,	,,	40	,,
Scotch pine	,,	,,	,,	38	,,
Spruce	,,	,,	,,	37	,,
Silver fir	,,	,,	,,	34	,,
Ash	,,	,,	,,	33	,,
Pedunculate oak	,,	,,	,,	17	,,
Beech	,,	,,	,,	16	,,

Thus, birch would yield the quantity of a full crop about every two years, while the beech requires more than six years.

Such figures are, however, liable to considerable variations, according to the local climate.

Another very important point is the size and nature of the seed. Species which have a small, light and winged seed reproduce themselves more easily and extensively, than those with a heavy or wingless seed. Moreover, it so happens that the species with light or winged seeds, such as birch, aspen, willow, Scotch pine and spruce, are comparatively less sensitive in respect of the factors of the locality, than, for instance, oak, beech, silver fir, maple and sycamore, with their heavy seeds. The consequence is that the power of reproduction peculiar to the first named species is much greater than that of the last mentioned. Instances where oak and beech are ousted by Scotch pine and spruce can frequently be seen, while the latter, in their turn, have to struggle against the inroads made on them by birch, aspen, and willow.

b. Reproduction from Stool shoots and Root suckers.

This method of reproduction applies to coppice woods. It occurs in two ways:—

Either: On that part of the stem which remains, after a

tree has been cut down, dormant or adventitious buds develop into shoots; they are called "stool shoots."

Or: Buds are formed on the roots, which develop into aërial shoots, such shoots being called "root suckers."

In both cases the nourishment and growth of the new individual depend on the continued root activity of the mother plant. If the new individual is capable of producing root buds and of developing them into roots, it becomes independent of the mother plant; in such a case, reproduction is established by a division of the mother plant.

Reproduction in the manner just described is strongest during youth, and the faculty is maintained, according to species, for different periods of time. The better the conditions of growth, the longer will the reproductive power be maintained. A thin and young bark reproduces more freely, than thick and old bark. Favourite places are the neck of the root stalk and wounds.

An essential condition of a copious reproduction in the manner described is full enjoyment of light; stools standing under cover develop either feeble shoots or none at all.

As regards species, the following classification may be made:—

The Reproduction is maintained beyond an age of 40 years in the case of: Oak, sweet chestnut, hornbeam, elm, alder.

It ceases at an earlier age in: Beech, birch, Norway maple, sycamore, ash.

The conifers have no power of reproduction of this class worth mentioning, as far as silviculture is concerned.

Some species produce only stool shoots, others only root suckers, and others again both:—

Principally stool shoots: Oak, hazel, hornbeam, beech, elm, sweet chestnut, lime, black poplar, alder, ash, sycamore, maple, willow, birch.

Principally root suckers: Aspen, white alder, Robinia, white poplar, and willows.

The age to which stools live differs considerably, according to species and locality. While the stools of oak and hornbeam last for centuries, those of beech are comparatively short lived. The osiers in the Thames valley, if coppiced annually, are said to last only about 10 years.

CHAPTER III.

CHARACTER AND COMPOSITION OF WOODS.

In silviculture, trees are only in exceptional cases reared in free positions; as a general rule they are grown in considerable masses, which form more or less fully stocked woods. These may be composed of one species only, or they may contain a mixture of two or more species; in the former case they are called *pure woods*, and in the latter *mixed woods*. Naturally pure woods occur only under certain conditions, as, for instance, when the factors of the locality suit only one particular species, or when the vitality and energy of one species has gradually ousted all others. Species which appear naturally in pure woods are called *gregarious*. In the tropics and sub-tropics, mixed woods prevail; on going north pure woods appear, and in the northernmost latitudes where forests exist, pure woods are frequent. In the countries round the Baltic and in northern Russia, pure woods of spruce, Scotch pine, larch and birch are of common occurrence, due to natural causes, and not to artificial interference. The same law holds good, more or less, on rising in mountains.

SECTION I.—PURE WOODS.

Practically, woods are rarely quite pure, because in most cases specimens of other species, which it was not intended to rear, make their appearance uninvited. As long as such an admixture is slight, accidental and not taken into account by the management, the character of the pure wood may be said to be preserved.

The principal advantage of pure over mixed woods is that they are easier to manage, because the requirements of only one species have to be considered. On the other hand, they

have often disadvantages as compared with mixed woods, which will be dealt with in section II. of this chapter.

The fitness of a species to be raised in pure woods depends on its capacity to preserve, or even improve, the factors of the locality, in other words, whether the species preserves a complete leaf canopy to an advanced age, and secures the preservation of a sufficient layer of humus. As indicated in section IV. of chapter I., beech, silver fir and spruce act most beneficially in this respect, and next to these Douglas fir and some of the pines. Apart from them, several others are frequently grown in pure woods, such as oak, larch, Scotch pine, and willows, on account of their great utility.

Of the remaining, or so-called *dependent* species, few are found in pure woods, and then only under special circumstances; for instance, hornbeam replaces beech in frost localities, Cembran pine and mountain pine occur at high elevations, maritime pine on dunes near the seashore, alder in wet localities, sweet chestnut as coppice for pit wood, hop poles, vine stakes, etc. On the whole, it may be said that dependent species may be grown as pure woods in the following cases:—

(1.) If the factors of the locality are such that an imperfect cover and want of humus do not materially injure them; as on deep fertile soils, which enjoy an ample and well distributed rainfall, or which are kept moist by ground water or irrigation.

(2.) If the woods are treated under a short rotation, so that they are cut over before any excessive interruption of the leaf canopy has set in; or if it is intended to underplant them when they commence to open out, as in the case of oak, larch, and Scotch pine.

(3.) If the object is to utilize localities which are only fit for one species; for instance, alder and willow on wet soils, hornbeam in frost localities, etc.

(4.) If only one species finds a ready market, or is required for a special purpose.

Except in such cases, all dependent species should be raised in mixed woods.

SECTION II.—MIXED WOODS.

A mixed wood may be so arranged that every tree of one species alternates with a tree of another species, in which case the mixture is called one *by single trees*. Or a group of trees of one species may alternate with a group of trees of another species, called a *mixture by groups*; in the latter case the groups must not be of such extent that each acquires the character of a pure wood. Mixtures may also be arranged in alternate *lines* or *strips*.

Mixed woods may be :—

(*a.*) Permanent or temporary.

(*b.*) Even aged or uneven aged.

Temporary mixtures are ordinarily called for in the following cases :—

(1.) When the intention is to obtain an early return by the removal of one of the species, which should in that case be of rapid growth.

(2.) When a tender species has to be protected (nursed) during early youth against frost or drought, as beech and silver fir, and to a less degree oak. In this case, a hardy and fast growing species, such as Scotch pine, larch, or birch, is raised, either simultaneously or beforehand, and removed when the tender species requires no further protection. Near the sea coast, it is generally necessary to grow first very hardy trees, so as to establish sufficient shelter; more valuable trees may afterwards be introduced between the nurses.

(3.) When both the above objects are combined.

Permanent mixtures are established, because they are considered to have advantages over pure woods.

1. ADVANTAGES OF MIXED WOODS.

These may be described as follows :—

(*a.*) Mixed woods admit of a more complete utilisation of the factors of the locality and consequently they may produce

a larger quantity of wood, if the mixture is suitably arranged. Each spot can be stocked with the species which is best adapted to the factors of the locality; hence, increased production may follow.

(*b.*) Unless very extensive areas are available, only mixed woods enable the forester to meet the various demands of the market. In the case of pure woods, and if a regular annual yield of each of several species is expected, a complete series of age gradations is required for each species, which, in the case of a limited area, would lead to small annual coupes. For instance, if the intention is to grow five species on an area of 500 acres under a rotation of 100 years, each cutting would extend, in the case of pure woods, over one acre, while in the case of a mixed wood, the annual cutting may be five acres in one block.

(*c.*) It has already been stated that only a few species are fit to be grown in pure woods. At the same time, many of the other species yield a very superior quality of timber, or valuable minor produce. All these would more or less disappear under the system of pure woods, or at any rate they would not thrive so well and would not develop equally fine boles, as if grown in mixed woods. Large sized timber of many light demanding species can only be produced by mixing them with shade bearing, and consequently soil preserving species.

(*d.*) Many species suffer less from external injurious influences, such as wind, fire, frost, snow, insects, fungi, if raised in mixture with other more hardy species.—A shallow rooted species had best be grown mixed with a deep rooted species.—Conifers are less exposed to damage by fire or snow, if mixed with broad-leaved species.—Insects are less dangerous in mixed woods, as they generally attack only one of several species; moreover birds, the great insect destroyers, are more numerous where broad-leaved trees grow, than in pure coniferous woods.—Damage by fungi to conifers is also considerably less if they are mixed with broad-leaved species.

—A hardy species mixed with a tender species protects it against frost, drought, and injurious air currents.

(*e.*) Mistakes made in the selection of species can be more easily rectified in mixed than in pure woods. The suitability of a locality for a certain species is not always apparent at the outset; in the case of mixed woods the species which is least suitable can be removed at the time of thinning.

(*f.*) For the above reasons, mixed woods will, in many cases, yield better returns than pure woods.

(*g.*) Finally, mixed woods increase the artistic beauty of a country.

2. Disadvantages of Mixed Woods.

It is frequently described as a disadvantage of mixed woods that their natural regeneration is more difficult than that of pure woods. No doubt, different species require different conditions, if natural regeneration is to be successful. More especially, the cover of the mother or shelter trees must be more open where a light demanding species is to be regenerated, than in the case of a shade bearing tender species. The shelter, for instance, which suits the beech, would probably kill young oak seedlings. Again, certain species, such as spruce, produce so much seed, spring up so easily, and would take possession of so much ground that other species, like silver fir and beech, would have little chance of coming up in sufficient numbers. In the Black Forest, silver fir has frequently to be helped against the beech. These objections are undeniable, but they are, after all, not of such importance as might appear at first sight. In the first place, the mother trees can be so selected that one species is favoured against the others. Secondly; the surplus regeneration of any one species can be removed in the first thinnings. Thirdly, the species can be arranged in small groups. Fourthly and chiefly, the best procedure is, to regenerate naturally with special reference to one species, and to introduce the others (as far as necessary) artificially. In the Black Forest, for

instance, silver fir is favoured in the regeneration, and spruce is, if necessary, afterwards planted in. In this manner, the forester can produce the desired proportion of the several species with almost mathematical accuracy. On the whole mixed woods offer substantial advantages over pure woods. At the same time it must not be forgotten that the treatment of pure woods is much simpler than that of mixed woods. Hence, the former may be preferable whenever really competent managers are not available.

3. Rules for the Formation of Mixed Woods.

The advantages of mixed woods, which have been detailed above, will only be realised under certain conditions, the more important of which are the following:—

(*a.*) the locality must be, *a priori*, suitable for the favourable development of each of the species in the mixture.

(*b.*) The mixture must be of such a nature that the factors of the locality do not suffer; they must, whenever possible, be improved. This will only be the case, if the principal, or more numerous, species is soil improving. As indicated above, exceptions occur when woods are treated under a short rotation, or when the quality of the locality is such that it does not require to be assisted by the improving action of the trees growing on it.

(*c.*) The mixture must be so arranged that one species does not oust the others, and establish a pure wood. The excessive development of one species may be detrimental to the others, or even kill them outright. In this respect the toughest and least sociable species carries the day, these qualifications being dependent on shape, light requirement and height growth of the species.

Shape.—Each species must be given that growing space which is required for its proper development. In this respect the several species differ considerably. Conifers, for instance, have a different shape from broad-leaved species. Again, some species are better able than others to stand an infringement

of their proper growing space. Thus, the broad-crowned oak is liable to suffer considerably in crowded woods, while spruce stands an infringement in space comparatively easily.

Light Requirement.—The mixture must be so arranged that the light demanding species are not likely to be shaded by other trees ; in fact, they must have their heads free and exposed to the light. Some species, such as silver fir and beech, like, and even require, some shelter during early youth. Mixtures should be so arranged as to provide such shelter, whenever it is required. After the first few years, no species actually requires shade, and then species are either shade bearing or light demanding. In most cases the former will bear the shade of the latter, but the reverse is not the case.

Height Growth.—All species, which demand space and light when mixed with species of an opposite nature, must be of quicker height growth than the latter, or be given a start. Hence, the relative height growth of the species must be fully considered in deciding on the nature of the mixture. In many cases it is necessary to produce woods of uneven age, in order to prevent the light demanding species from being overgrown and suppressed by the other species.

Assuming then that the locality suits in a general way all the species to be mixed, the following rules govern the selection and formation of mixtures :—

First Rule.—The ruling (more numerous) species must be soil improving.

It has been stated above under what conditions exceptions from this rule are admissible.

Second Rule.—Shade bearing species may be mixed with each other, provided their height growth is of the same rapidity, or the slower growing species can be effectually protected against the faster growing.

Third Rule.—Shade bearing species may be mixed with light demanding species, if the latter are either faster growing, or are given a start.

To prevent the shade bearing species being kept back in its growth, it should be more numerous than the light demanding species.

Fourth Rule.—Two or more light demanding species should not be permanently mixed, because the soil deteriorates, and the faster growing suppresses the slower growing species.

Exceptions to this rule are admissible :—

(*a.*) On very fertile localities.

(*b.*) On very inferior localities, where nothing else will grow.

(*c.*) If the wood is treated under a short rotation, or as coppice, or if it is intended to underplant the wood at an early age with a shade bearing and soil improving species.

Temporary mixtures of two or more light demanding species occur frequently, especially where a slower growing species has to be protected against frost or drought; for instance, oak with nurses of larch, Scotch pine, or birch.

Fifth Rule.—The circumstances of each case must decide whether the species should be mixed by single trees, groups, lines, or strips.

Two shade bearing species of equal height growth, for instance, may be mixed by single trees, but if the quality of the soil changes from place to place, it may be desirable to arrange the mixture by groups, placing each species on the more suitable spots. Again, if a light demanding species is to be raised with a faster growing species, the mixture should be by groups, and not by single trees. In such cases the groups are sometimes given the shape of strips. Oak and beech are now so mixed in the Spessart mountains that the groups of oak extend over areas ranging from one to ten and even more acres, the rest of the area being taken up by beech. In this way the suppression of the oak by the beech is prevented; it is later on underplanted with beech, if it does not appear naturally.

All mixtures may be brought under one of the following three classes :—

Mixtures of shade bearing species.

Mixtures of shade bearing and light demanding species.

Mixtures of light demanding species.

4. Mixtures of Shade-bearing Species.

It is a general rule that the permanent preservation of a mixture becomes more difficult in the same degree as the species to be mixed differ in respect of light requirement, rate of height growth, suitability of locality, and shape of trees. Except as regards the latter, the ordinary European shade bearing species approach each other in these respects ; hence, in their case the mixture is comparatively easy to maintain, and they may generally be raised in woods of even age or nearly so.

a. Mixtures in High Forest.

(1.) *Silver fir and spruce.*—These two species resemble each other as regards shape. They differ somewhat in their demands on the locality, but over extensive areas both find suitable conditions for a healthy development. They are both shade bearing, but silver fir more so than spruce. The most important point is, that spruce grows somewhat more quickly during youth and is likely to injure the silver fir, but when the latter has once pushed its head to the light, the two species hold their own against each other. In order to get the silver fir safely over the first 20 or 30 years it must be assisted against the spruce, either by giving it a start of 5—10 years, or arranging the mixture according to groups, or cutting away the spruce where it threatens the silver fir. Where mixed woods of silver fir and spruce have to be re-generated, it is usual to leave a larger number of silver fir seed trees, and to keep the shelter wood rather dark. In this way, a larger proportion of young silver fir is secured ; then more light is given to enable young spruce to come up, and if

this should not happen, the species is brought in by planting.

The advantages of the mixture are principally the following:—

(*a.*) Spruce protects silver fir against frost and drought during early youth.

(*b.*) Silver fir protects spruce against storms in after life.

(*c.*) Spruce, when mixed with silver fir, is somewhat less exposed to damage by insects and snow.

(2.) *Silver fir and beech.*—They differ in shape but make very similar demands on the locality. Both are highly shade bearing. Beech grows somewhat more quickly in youth but more slowly in after life. During the former period silver fir, and during the latter, beech must be somewhat assisted, or the mixture arranged by groups. Both species thrive better in mixture, which is altogether an excellent one.

(3.) *Spruce and beech.*—They differ in shape, and make somewhat different demands on the locality, especially in respect of the degree of moisture and depth, spruce requiring more moisture, and beech greater depth. Nevertheless, soil which is suited for beech, will also do for spruce, but not always the reverse; in the moister parts, spruce should predominate, and in the drier parts beech. Both are shade bearing, spruce less so. The rate of height growth is a more serious matter. During youth, beech grows sometimes more quickly, but in other cases the spruce; later on the spruce is the faster grower; they must be protected accordingly, the one against the other. On the whole, beech is more in danger of being suppressed than spruce, because under ordinary circumstances the latter is more pushing and aggressive. Spruce is only threatened in localities which are specially suited to beech.

Beech has a most beneficial effect upon spruce in respect of danger from wind, snow, insects, and fire. At the same time, beech produces finer boles in this mixture, than if grown pure. Where beech timber is little in demand, it should not

occupy more than about $\frac{1}{4}$th of the area against $\frac{3}{4}$ths occupied by the spruce.

(4.) *Beech and hornbeam.*—This is a mixture of subordinate importance. The timber of hornbeam is frequently more in demand, but beech yields a larger volume. Hornbeam grows somewhat more quickly at first, but on the whole it is left behind by beech. In some localities, especially those exposed to frost, hornbeam forms a suitable substitute for beech in mixed woods.

(5.) *Douglas fir* may be mixed with beech, silver fir or spruce; it grows faster than either of these.

b. Mixtures in Coppice Woods.

In coppice woods it is always desirable to mix some hornbeam with the beech, because the latter by itself is rarely able to maintain a full crop, owing to its inferior reproductive power from the stool; hornbeam is possessed of a great reproductive power by stool shoots.

In coppice with standards also, the underwood should consist, at any rate partly, of hornbeam, and not altogether of beech.

5. Mixtures of Shade bearing with Light demanding Species.

While the shade bearing species much resemble each other in character, considerable differences exist between light demanding and shade bearing species in respect of shape, height growth, light requirement and duration of life; hence, the maintenance of such mixtures requires great care and skill.

Most of the light demanding species, such as oak, larch, Scotch pine, ash, as well as the moderate shade bearing Norway maple and sycamore, are raised principally for timber, and less for firewood; they require full enjoyment of light throughout life, but they cannot reach timber size and maintain the factors of the locality without the assistance of

the shade bearing species; in order to meet the requirements of the case *it is generally necessary to grow uneven aged woods.*

The principal object in all such mixtures is the full development of the timber yielding, light demanding species, while the shade bearing species, though more numerous than the former, practically take the second place in importance. The light demanding species which deserve special mention in this place are:—Larch, Scotch pine, oak, ash, sweet chestnut and elm; also Norway maple and sycamore, which stand about half-way between light demanding and shade bearing species.

a. Mixtures in High Forest.

(1.) *Larch in mixture with shade bearing species.—Larch and spruce.*—If the two species are of the same age, the larch goes ahead at once and leaves the spruce behind. On soil which suits the larch, the tree will not be caught up by the spruce before the 40th or 50th year or even later, when they will grow up together, provided the spruce has not been killed by the larch before that time. On localities which are less suited for larch, the spruce will catch it up much earlier, by the 15th or 25th year, pass and suppress it, so that it gradually disappears. In such cases the larch must be given a start, the result being an uneven aged wood. The best method is, to raise larch pure, and to bring in the spruce when grass begins to replace the moss, that is to say, at the age of 15—30 years. When the spruce has established itself, all larches, which are not likely to develop into fine trees, should be removed.

It is well known how much larch suffers from canker when grown outside its natural home. Until means have been found by which that disease can be prevented, the only way to reduce the damage to a minimum is to isolate the larch trees, by mixing them with another species, for which spruce is fairly well adapted, though not as well as silver fir and beech.

Larch and silver fir.—This is a better mixture than larch and spruce, as silver fir stands more shade than spruce; the ultimate height growth is much the same. As silver fir requires better soil than spruce, the larch thrives admirably in all localities where silver fir grows, provided the mixture is judiciously arranged.

Larch and Douglas fir.—A good mixture, but it is desirable to place the species into alternate lines, so as to exercise a proper control over each. Of late years, larch has been under-planted with various exotic trees, such as Douglas fir, *Abies grandis, Thuia plicata, Tsuga Albertiana, Picea sitkensis,* and others. It is too early to discuss the results.

Larch and beech.—This is an excellent mixture. Larch grows quickly enough to maintain itself in the even aged form, but it is still better to start with pure larch and bring in the beech, when the former is 15 to 30 years old. The most suitable localities are those with a fresh deep soil on northerly or easterly aspects.

(2.) *Scotch pine in mixture with shade bearing species.*—The Scotch pine very much resembles the larch in its bearing towards the shade bearing species. The even aged form does fairly well in the majority of cases, provided the shade bearing species are in youth protected against the Scotch pine. In the uneven aged form, spruce, silver fir, or beech need not be brought in until the Scotch pine has reached the age of 20—40 years, as it begins to thin out somewhat later than the larch. The Scotch pine must not be too numerous, or its shade will injure the other species in the uneven aged as well as during youth in the even aged form.

Both Scotch pine and larch afford excellent protection against frost and drought to silver fir and beech during their tender youth, and also to spruce, though the latter requires such protection in a less degree than the former two species.

Scotch pine and hornbeam occur sometimes together, especially in frost localities, where the hornbeam replaces the beech.

Hornbeam is liable to suffer considerably from the shade of the Scotch pine, so that it is frequently reduced to an underwood, which may be periodically coppiced.

(3.) *Oak in mixture with shade bearing species.—Oak and spruce.*—Natural mixtures of oak and spruce are rare, owing to the different character of the two species. Oak is at home in low warm situations, spruce in cool high places. Oak thrives best on loose, warm, deep soils with a good measure of water in the subsoil; spruce requires moisture near the surface, and it is satisfied with a moderately deep soil. Oak requires much light, heat and space; the demands of spruce are more moderate in these respects. Oak is inclined to develop large branches; spruce grows more in height. Nevertheless, artificial mixtures of the two species are advocated by some foresters. Oak grows faster than spruce during early years; later on spruce passes the oak, and the latter has no chance if mixed by single trees in even aged woods. It is necessary to place the oak in groups, and even then it does not always develop satisfactorily. The best arrangement is to plant oak pure and to bring in the spruce when the oak begins to thin out. It has, however, been noticed that the oak becomes stag headed when underplanted with spruce, a phenomenon which is by some foresters believed to be due to the great consumption of water by the spruce; hence, the mixture is only admissible under favourable conditions, or when the spruce is cut out at a comparatively early age, before it has had time to injure the oak.

Oak and silver fir.—This is a better mixture than that of oak and spruce, as the two species resemble each other more in their demands on the locality. Oak requires a start, or it will be passed at about middle age and suppressed by silver fir. The best plan is to plant oak pure, and to bring in silver fir when the former begins to thin out. Even then, the mixture has lost many adherents of late years.

Oak and beech.—This is a most suitable mixture, as the two species stand sufficiently near each other in respect of locality

and shape; moreover, they are found naturally together. The beech has been called the oak's nurse. The oak finds in the mixture all the advantages of a permanent, complete shading of the ground, accompanied by a heavy fall of leaves, a thick layer of humus, and freshness of the soil; it thus attains great height and a clear bole of considerable length.

The oak requires to have its head free throughout life. It grows more quickly than beech if the climate and soil suit it thoroughly in respect of moisture and depth. In such localities the mixture may be arranged by single trees. In the majority of cases, however, the oak is left behind by the beech, and then the former, in single trees, is lost; hence, the mixture must be arranged by groups, or all threatening beeches cut back or removed; or the oak is given a start, the beech being brought in when the oak commences to thin out, that is to say, between the 30th and 50th year, according to circumstances.

Oak and hornbeam.—This mixture may be desirable in localities which do not suit the beech, as for instance in frost localities, or moist deep sandy soils of the low lands. The oak grows quickly enough to hold its own against hornbeam. In this mixture the hornbeam is frequently treated as coppice.

(4.) *Norway maple and sycamore in mixture with more shade bearing species.*—Such mixtures require a fresh, deep and fertile soil. During early youth both maple and sycamore grow more quickly than spruce, silver fir, and beech, but later on they are passed by the shade bearing species. Hence, it is necessary to place the maple and sycamore in groups, or to give them a start in age; by far the best mixture is that with beech.

(5.) *Ash in mixture with shade bearing species.*—The best mixture is ash and beech; not so good is that of ash and silver fir, and still less that of ash and spruce.

Ash, like the maples, grows first more quickly than beech, but is generally passed by the latter later on; hence, it

should be placed in groups in the moister parts of the locality. Where ash occurs pure, it should be underplanted with beech or hornbeam long before its height growth has been completed.

(6.) *Elm in mixture with shade bearing species.*—Elm does best in mixture with beech, or perhaps hornbeam. The mixture of elm with spruce and silver fir is less desirable. Elm requires a locality with sufficient warmth, or else it will not develop into a large-sized tree; it also requires a deep fertile soil. Elm grows at first more quickly than beech, but afterwards it is liable to be passed; hence it must be placed in groups, or given a start. The groups of elm should subsequently be underplanted with beech.

(7.) *Birch in mixture with shade bearing species.*—Such mixtures occur naturally. The light seed of the birch settles on all blanks, large or small, and too often interferes with the shade-bearing species.

Birch and beech.—The birch should only form a moderate admixture by single trees; if it is more numerous, a part should be cut back. Birch becomes ripe for the axe long before the beech.

Birch and silver fir.—After some time the silver fir outgrows the birch, which is then likely to be suppressed.

Birch and spruce.—The birch injures the spruce by a whip-like action of its branches, but spruce soon passes and suppresses birch.

(8.) *Lime, aspen, and willow in mixture with shade bearing species.*—Like birch, these species appear naturally amongst shade bearers, more especially in beech woods, where they often do damage owing to their rapid growth in early youth. If it is desired to produce large specimens of these species, they must be reduced to moderate numbers. In after life, beech passes and suppresses them, if allowed to do so.

b. Mixture in Coppice with Standards.

The greater part of the mixture consists of broad-leaved species, but conifers (larch, Scotch pine, etc.) are not excluded

as standards, so that an opportunity is given for the production of any or all species.

It must be a leading principle to let the light demanding species prevail in the standards or *overwood*, and the shade bearing species in the coppice or *underwood*. At the same time, some individuals of the latter species may be represented in the overwood, for the purpose of producing seed to meet the requirements of natural regeneration.

The overwood should consist of healthy trees which, if possible, have been raised from seed. Only in exceptional cases should vigorous coppice shoots be allowed to grow into standards.

In some cases all ages are mixed by single trees, in others the several age gradations are arranged in small groups. As the coppice shoots at once grow rapidly, seedlings have no chance of making their way up, unless they are strong, and are protected against the coppice shoots.

As each standard must be cut when it has reached the highest degree of usefulness, it follows that larch, Scotch pine, birch, and also ash will fall under the axe before the oak, elm, maple, or sycamore have reached a useful size; hence, the former do not appear in the oldest age classes.

c. Mixture in Coppice.

The principal species are beech, hornbeam, elm, ash, maple, sycamore, lime, oak, sweet chestnut, birch, hazel, willow, aspen, alder, etc.

Beech is more slowly growing than the light demanding species, and requires some protection against them except on very fresh and fertile soils. Ash, Norway maple, sycamore, and oak are liable to suffer from too large a proportion of birch, hazel, and willow.

6. Mixtures of Light demanding Species.

As indicated above, such mixtures are justified only in exceptional cases. Generally, they are objectionable as long as the admixture of a shade bearing species is practicable.

All mixtures of light demanding species thin out sooner or later according to the degree of light requirement and the tendency towards branch formation of the species, as well as according to the quality of the locality. When once that period has arrived, the factors of the locality must suffer. Exceptions are woods growing under favourable conditions, temporary mixtures and shelter-woods.

Generally, only the even aged form is admissible, and even then such mixtures require constant attention, so as to prevent one species being suppressed by the other.

a. Mixture in High Forest.

(1.) *Oak, with ash, elm, or sweet chestnut.*—These mixtures require a fertile, deep, moist soil and a favourable climate. Oak is slower growing during early youth, and in many cases also later on; hence it is liable to be suppressed. At any rate it rarely finds sufficient space for favourable development, being closely pressed by the other light demanding species. It does better if placed in groups.

(2.) *Oak with alder and birch.*—This mixture occurs on wet soil, where the oak occupies the drier parts of the locality. If mixed by single trees, the oak is speedily suppressed.

(3.) *Oak with Scotch pine or larch.*—Such mixtures are made because oak helps to protect the Scotch pine against damage by insects, snow, etc., and larch against canker, while Scotch pine and larch protect the oak during youth against frost and drought. If for the latter purpose, the mixture is frequently of a temporary nature, or only a few Scotch pines or larches are allowed to remain when the oak does no longer require shelter.

(4.) *Scotch pine with birch.*—This mixture occurs naturally, and yet it cannot be recommended, because such woods are always very thin and the soil deteriorates. They are generally the result of unfavourable conditions, in localities where no other species can compete with Scotch pine and birch.

Up to 15 or 20 years, birch grows quicker; the Scotch pine,

if it survives that period, comes up and passes it; the birch then requires help, if it is to be preserved. Birch falls under the axe at a comparatively early age, and an open wood of Scotch pine remains. Only on good fresh soil does birch last until the Scotch pine has reached a marketable size.

At the same time, birch may be a desirable admixture, where the object is to protect the Scotch pine against insects, snow, fire, etc., and where a more suitable mixture is impracticable.

(5.) *Scotch pine with larch.*—This mixture leads to unsatisfactory results whenever the locality is not thoroughly suited to larch. During youth, up to 15 or 20 years, larch grows quicker and may injure the Scotch pine. If the latter makes its way up and begins to press round the larch, the latter may require help.

Nevertheless, this mixture occurs over extensive areas in the United Kingdom, more especially in Scotland, not because it is the best that can be devised, but because Scotch pine thrives well and yields higher returns than most of the shade bearing species which could be substituted for it.

Other mixtures, in which the Scotch pine is the principal species, are:—

Scotch pine with Corsican pine; a good mixture.
" " " Weymouth pine; a good mixture.
" " " Austrian pine; the latter disappears as it is slower growing, unless it is helped.
" " " sweet chestnut; the latter often becomes a soil protection wood.

In England sweet chestnut is sometimes mixed with larch.

(6.) *Alder with birch and aspen.*—This mixture occurs in wet localities, where nothing else will grow.

b. Coppice, and Coppice with Standards.

Woods of coppice with standards consisting of light demanding species only are comparatively rare, as the

standards must either be very few in number, or the underwood suffers. Under any circumstances, such mixtures require a fertile moist soil. Mixtures of this kind are, for instance—

Ash and alder, or

Oak, sweet chestnut, ash, elm, and others; also hazel.

Where ash and alder appear in mixture, the former should, generally, be the overwood, and the latter the underwood; it occurs in wet localities. In the even aged mixture, ash is liable to be killed out. In fertile low lands, oak and ash appear as overwood and underwood, mixed with various other species, as elm, chestnut, etc. Short stems of the standards are often the characteristics of such mixtures. Their number must be small, or the underwood suffers.

Coppice woods coming under this heading are mixtures of oak, ash, birch, lime, aspen, sallow, hazel, and more especially oak with sweet chestnut. In such mixtures Scotch pine and larch often find a temporary place as small standards.

Another mixture is that of sweet chestnut and Robinia, generally by groups, or else the Robinia is likely to suffer.

CHAPTER IV.

THE SILVICULTURAL SYSTEMS OR METHODS OF TREATMENT.

By a silvicultural system is understood the systematically arranged method according to which the formation, regeneration, tending, and utilization of the woods, which compose a forest, are effected.

The character of each system depends in the first place on the method of formation or regeneration, and consequently all systems must come under one of the following three heads :—

(1.) High or seedling forest.

(2.) Coppice forest.

(3.) A combination of seedling and coppice forest.

Owing to the varying character in the factors of the locality, the composition of woods, and the many different purposes for which they are grown, the above three main systems have been split up into a number of variations. In the case of high forest, the principal distinction is, whether the new wood is created on a clear cutting, or under the shelter of an existing wood. In the latter case, the regeneration may be effected at the same time in a uniform manner over a considerable area (compartment), or over certain groups, or by the removal of single trees here and there. Coppice woods may consist of stool shoots or of pollards. Again, a number of auxiliary systems have been evolved out of the principal systems by means of certain modifications or additions.

It is not intended to describe here all* existing modifica-

* Mayr enumerates seventy-three different forms.

tions, but the more important systems may be classified as follows:—

I. Principal Systems:—

A. High or Seedling forest—

1. Clear cutting and subsequent regeneration . 1

2. Regeneration under a shelter-wood:

a. By treating one or several compartments in an uniform manner 2

b. „ groups 3

c. „ single trees 4

B. Coppice forest 5

C. Combination of seedling and coppice forest . . 6

II. Auxiliary systems—

1. High forest with standards 7

2. Two-storied high forest 8

3. High forest with soil protection wood . . 9

4. Forestry combined with the growth of field crops 10

5. Forestry combined with pasture 11

6. Forestry combined with the breeding of deer and other game 12

SECTION I.—DESCRIPTION OF SYSTEMS.

In considering the various systems the following points deserve special attention:—

(1.) Origin and character of wood.

(2.) External dangers peculiar to the system.

(3.) Quantity and quality of produce.

(4.) Effect of the system upon the factors of the locality.

The remarks on each of the twelve systems will be arranged under these four heads.

1. System of Clear Cutting in High Forest.

a. Origin and Character.

The wood is originated on an area, which is clear of trees, by direct sowing, or planting, or occasionally by seed coming

from adjoining woods. The young trees are all of the same age and height (or nearly so); as soon as the branches begin to interlace, the trees form an uninterrupted leaf canopy overhead, which, with advancing years, becomes more and more elevated above the ground, leaving a space below, in which the branchless trunks or boles of the trees tend upwards.

In a wood of this class the sunlight reaches only the upper parts of the crowns, the result being that height growth and

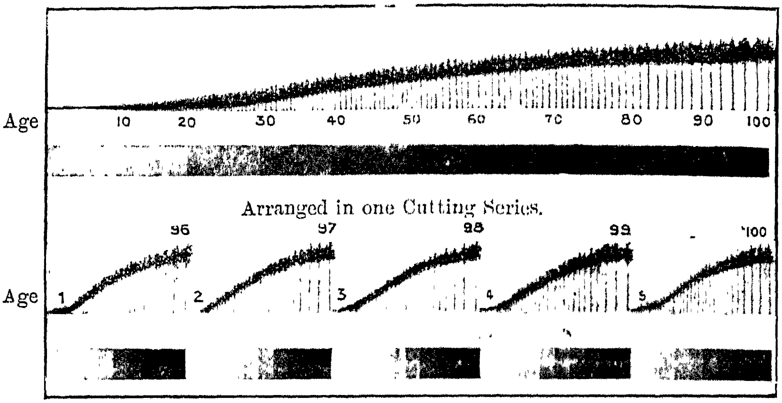

Fig. 5.—A normal Series of Age Gradations, treated under the Clear Cutting System.

the formation of clear boles are specially favoured. The density of the cover, and with it the diameter growth, depend on the character of the species, the quality of the locality, and the degree of thinning. At the end of the rotation the wood is cleared off the area, and the process of formation recommenced.

b. External Dangers.

The principal dangers are those of frost, drought, insects and storms. In early youth, a wood formed on a cleared area is exposed to all meteoric influences. In winter, and especially in spring and autumn, frost threatens the young plants, if they are at all sensitive to it, and in summer the uninterrupted

xposure to the sun may dry up the soil and plants; they may lso be seriously injured by a strong growth of weeds. Moreover, air currents strike over the area without obstruction. All these agencies interfere with a uniform degree of moisure. There can be no doubt that many diseases, which perhaps appear only later on, can be traced as having originated during this period of early exposure. At that time, the greater dryness of the soil attracts insects, which concentrate their breeding places on the area.

Whether woods produced under this system are more subject to damage by storms than woods produced under shelterwoods is doubtful, varying views being held on the subject. On the one hand, trees of even age standing in crowded woods protect each other, but on the other hand, individually they do not stand as firm as trees grown up in a more free position, or in woods of uneven age. As regards damage by snow and ice, the system gives less favourable results, than one producing uneven aged woods.

c. Production of Wood.

As regards production, the system compares favourably with other high forest systems, especially if the woods are created by planting. The quality of the timber is also of a very high class, if the thinnings have been judiciously carried out. More especially, long clean non-tapering boles are produced under this system, to which a good diameter can be added by thinning strongly during the second half of the rotation.

d. Effect upon the Factors of the Locality.

This effect differs much during the several periods of the life of the wood. During early youth, before a complete leaf canopy has been established, the soil is exposed to the effects of sun and air currents, both of which act highly injuriously on the soil. Subsequently, when a good cover has been established, the very opposite effect is produced in a high degree.

Later on in life again, when the crowns, with advancing age, have been elevated far above the ground, the sun is still kept out, but there is no impediment to air currents striking through the wood, so that moisture is carried away, and the activity of the locality frequently considerably reduced by the time regeneration is commenced.

It follows that the system has decided disadvantages where the supply of moisture is limited. At any rate, production is subject to considerable fluctuations. In the case of shade bearing species with dense crowns, provided they are hardy, the system yields evidently much better results than in the case of light demanding species with thin crowns. The length of the rotation also affects the results.

The extent, to which the disadvantages of the system make themselves felt, depends on the size of the clear-cutting. It is greatest where a large area in one piece is clear cut at the same time. Hence, the cutting areas should be as much as possible reduced, and a fresh cutting adjoining the former one should not be made, until the young crop on the latter is fairly safe against injurious influences. The cuttings frequently take the shape of narrow strips, the breadth being equal to once or twice the height of the old wood; they may, however, be of considerable length, provided they are situated on that side of the wood which is to the leeward of the prevailing wind direction.

2. The Shelter-wood Compartment or Uniform System.

a. Origin and Character.

The wood is formed, or regenerated, under the shelter of the whole or part of the old crop, which forms a shelter-wood, and which is retained for some years, until the young generation has established itself and is safe against injurious external influences peculiar to early youth. The regeneration is effected, according to circumstances, by the seed falling from the shelter trees, which in that case become mother trees, or

by sowing or planting. In the former case, the regeneration is said to be *natural*, in the latter *artificial*. In the case of natural regeneration, though the area is treated in an uniform manner, one seed year is rarely sufficient; as a rule two or three such seed years are required, and often artificial cultivation has to assist, in order to produce a full new crop; hence, the latter shows in the majority of cases differences of age ranging up to perhaps 15 years. Nevertheless, such differences will no longer be discernible, when the wood approaches the

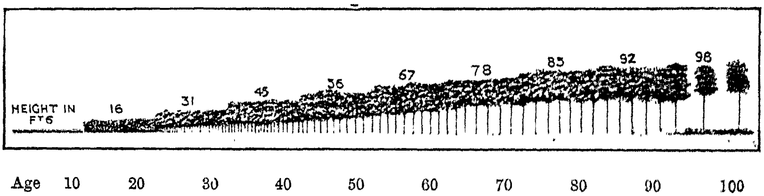

Fig. 6.—A normal Series of Age Classes, treated under the Uniform System.

end of the period of principal height growth, and, for all practical purposes, such woods are considered as even aged.

b. External Dangers.

Owing to the presence of the shelter-wood, the danger from frost, drought and weeds during youth is very considerably reduced, if not altogether obviated; during the rest of life, no difference exists in this respect between this system and the system of clear cutting. There is no doubt that such woods are less attacked by insects than those raised on clear cuttings. The chief difference as regards storms is that the shelter or mother trees are liable to be thrown.

c. Production of Wood.

The quantity of total production is probably the same as in clear cutting. As regards quality, it should be noticed that the mother trees are in a position to attain a specially large size (diameter), owing to their comparatively free position during the last period of life. At the same time, much damage is frequently done to the young crop during their removal.

d. Effect upon the Factors of the Locality.

The unfavourable effect of sun and air currents during the early youth of the wood disappears under this system, as the shelter-wood protects the soil until the new crop can relieve it of this duty. In after-life no difference exists between this system and that of clear cutting.

A modification of this system is the "Shelter-wood Strip System." Under this system each compartment is divided into a number of narrow strips, which are successively taken in hand. Regeneration commences, as in the case of clear cutting, on the lee side of the wood, and gradually proceeds, at suitable intervals, in the direction whence the prevailing wind blows. By reducing the area taken in hand at one time, the disadvantages of the system are so considerably minimised, that it has gained more and more ground of late years. The wood, as a whole, becomes uneven aged, the gradations being arranged in strips, thus leading to the formation of cutting series, a subject which is dealt with in Volume III. of this Manual.

3. The Shelter-wood Group System.

This is another modification of the shelter-wood compartment system.

a. Origin and Character.

The wood is formed, or regenerated, under the shelter of the old crop, but instead of treating a whole (or several) compartment in an uniform manner at one time, with a view to its simultaneous regeneration, only certain groups of trees, scattered here and there over it, are dealt with in the first place; when these have been regenerated, others are treated in the same way, and so on, until the whole compartment has been regenerated. Frequently the later groups take the shape of belts running around the groups first taken in hand, so that the groups finally merge into each other. The regeneration period extends over not less than thirty, and

often forty or fifty years, during which the old wood is gradually led over into the new wood. At the end of the regeneration period, the new wood consists of a series of groups, of greater or smaller extent, ranging in age from one to thirty, forty, or fifty years, according to circumstances, and it presents a picture of unevenness which is preserved throughout life. The wood grows on until the next regeneration comes round, when operations are commenced in the oldest groups and gradually extended to the youngest, similar to the procedure followed in the first instance.

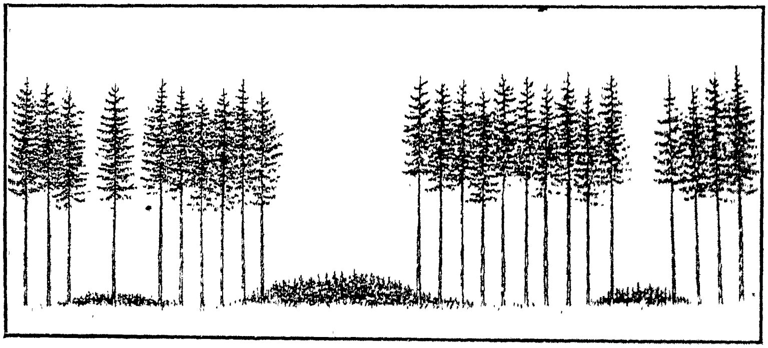

Fig. 7.—The Group System of Natural Regeneration.

During regeneration all seed years are taken advantage of, and artificial help, where necessary or desirable, is also given.

The group system is frequently combined with the strip system, mentioned above.

b. *External Dangers.*

Owing to the uneven age of the several groups, the young growth receives both top and side shelter; hence, it is more fully protected against frost and drought than under the shelter-wood compartment system. It is also claimed for the system that the trees withstand storms and damage by snow

or ice better, except during regeneration, when the shelter trees are liable to be thrown by wind.

c. Production of Wood.

Whether the total production is greater or smaller than under either of the previously mentioned two systems, can only be proved by actual statistics in the course of time; the system affords the means of producing valuable large timber, as, towards the end of the rotation, the finest trees can be placed comparatively free for a considerable number of years.

d. Effect upon the Factors of the Locality.

This is doubtless more favourable than under the shelter-wood compartment system, as the soil is more carefully sheltered, accompanied by a more complete preservation of an even state of moisture.

4. THE SHELTER-WOOD SELECTION SYSTEM.

a. Origin and Character.

The forest is created, under the shelter of the old crop, by the removal of single trees or small groups selected here and there over the whole area, and this process goes on throughout the whole length of the rotation, so that practically no part of the whole forest is ever at rest. All age classes, from one year old to the oldest, are constantly represented, by single trees or small groups, over the whole area, and, theoretically, the work of selecting trees for cutting extends at all times over the whole extent of the forest. In practice, however, the forest is divided into a number of blocks, which are gone over in turn, so that cutting returns to the same part only after the lapse of several years.

b. External Dangers.

Views differ somewhat regarding the extent to which selection forests are exposed to external dangers, as compared with the two previously mentioned shelter-wood systems. In the

author's opinion, the system is the most favourable of the three, because only very small plots are, at one time, exposed to sun and air currents. Damage by frost is less, and probably the same holds good as regards wind and snow.

c. Production of Wood.

Here again, actual comparative observations are not available. It has by no means been proved that less wood per acre and per annum is produced under this than under either of the two previous systems. Young growth, no doubt,

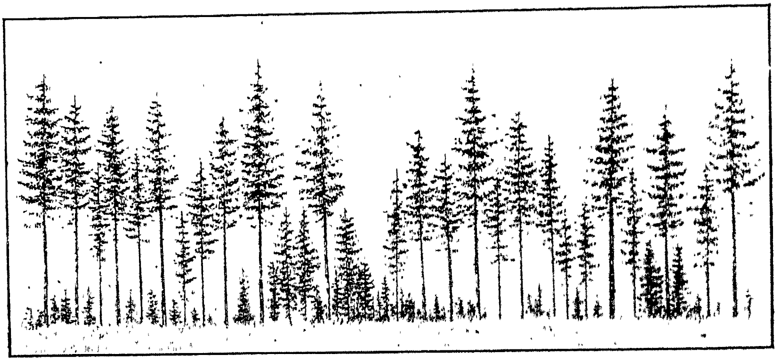

Fig. 8.—The Selection Forest.

develops slowly, as it is much interfered with by the adjoining older trees, but this may be compensated for by a more active development, when the trees have secured the full enjoyment of light, especially during the more advanced period of life. There can, however, be no doubt that less clean and shorter boles are produced under the selection than under the uniform system, though the former is specially suited for the production of large sized timber, as each tree can be left in the forest until it has reached the desired dimensions.

d. Effect upon the Factors of the Locality.

The system secures an almost absolutely equal degree of protection of the soil throughout the rotation, more especially

as regards the preservation of an even degree of moisture, which must act beneficially upon production. Protection is given not only from above, but the uniform mixture of old and young trees also secures lateral shelter.

On sloping ground, rain water is more effectively retained under this than under any other system; avalanches also, the carrying away of fine earth, landslips, etc., are prevented or at any rate moderated; hence, protection forests situated in mountains are usually worked under this system.

5. The Coppice System.

a. Origin and Character.

Most broad-leaved species have the faculty of reproducing themselves by shoots, which spring either from the roots, stool, or stem. After severing the whole, or part, of the stem above ground, the roots or stool develop shoots, which grow up into poles, and, under favourable conditions, into trees, thus producing a new generation. This process of regeneration can, as a rule, be repeated as long as the stool and roots continue to live.

When the trees are cut over close to the ground, *simple or ordinary coppice* is produced, the shoots starting from a point which is close to, or in, the ground. Generally, a number of shoots spring from the same stool, and these stand in clumps, and can easily be distinguished from seedling trees. On well stocked areas, a complete cover is established earlier under this system than in seedling forests, as the shoots develop very rapidly during the first few years. When the cover has been established, the wood presents the appearance of an ordinary thicket in high forest.

If the trees are cut over at some height, say several feet, from the ground, the shoots appear at the upper end of the stem, which may be said to form a new crown. In that case, the method becomes the *topping system.* If the main stems remain intact, or nearly so, and only the side branches are

cut over, the method is called the *pollarding system.* No distinct line can, however, be drawn between these two systems, and in many cases topping and pollarding must be considered as synonymous terms. In either case, the trees may be cut over repeatedly, just as in ordinary coppice.

b. External Dangers.

Coppice suffers more than seedling forest from late and early frosts, because the shoots grow up quickly, are full of sap, and consequently require a longer growing period in order to ripen before the autumn frosts set in. On the other hand, damage by frost is more easily repaired in the case of coppice, as new shoots will replace those injured during the first year. Coppice suffers much more from damage by game, especially deer and rabbits. Mice also are injurious. In respect of other sources of damage, coppice is less affected than high forest.

c. Production of Wood.

Coppice yields chiefly firewood and small timber, such as pit timber, hop poles, vine props, rafters, withies for basket work, etc. Oak coppice woods are cultivated for the sake of the bark, which is used for tanning. The number of cubic feet of wood produced per acre and year is generally smaller than in the case of high forest.

d. Effect upon the Factors of the Locality.

Owing to the rapid growth of the shoots and the quick establishment of a complete cover, coppice woods protect the soil well after the first few years, but the latter is laid bare at much shorter intervals than in the case of high forest. The higher the rotation, the more nearly does coppice wood approach the character of high forest; as a rule, however, the rotation is short, and the wood does not reach that age at which air currents obtain free access underneath the crowns.

6. The Coppice with Standards System (Stored Coppice).

a. Origin and Character.

The system of coppice with standards is a combination of the following two systems:—

(1.) Simple coppice of even age.

(2.) Standards of uneven age treated under the high forest selection system.

The coppice forms the underwood, and the standards the overwood, the two being treated under different rotations. Generally, cuttings are made in both underwood and overwood at the same time; that is to say, when the underwood has arrived at the end of its rotation, it is cut over, and at the same time those standards are removed which have reached the end of the rotation fixed for the overwood, or which it is desirable to remove for other reasons. New standards are then introduced, which, as a rule, should be seedlings and not coppice shoots. It follows that, theoretically, the several gradations of the overwood show a difference in age equal to one rotation of the underwood, and the age of the oldest standards at the time of cutting is a multiple of the number of years contained in the rotation fixed for the underwood.

Example.

Rotation of underwood	=	20 years.
Rotation of overwood	=	100 ,,
Number of age gradations in overwood .	=	$\frac{100}{20} = 5$

At all times the youngest age gradation forms part of the underwood, until the latter is cut over.

Every standard removed at the end of the rotation must be replaced by younger trees. If all seedlings reached the end of the rotation, only one need be planted for every full-sized standard which has been removed, but as numerous trees have, owing to various causes, to be taken out before the end of the rotation, it is necessary to plant several seedlings for every matured standard removed, so that, as a matter

of fact, the numbers of the standards in the several age gradations always form a falling series. The actual proportion of trees in each age gradation depends on circumstances. In the above-mentioned example the proportion would be somewhat as follows :—

Number of age gradation . .	I.	II.	III.	IV.	V.
Proportion of standards . .	20	12	3	2	1.

In other words, for every desired standard 100 years old or more, it is necessary to have 20 standards 20 years old, which

Fig. 9.—Coppice with Standards.
Rotation of underwood = 20 years.
Rotation of standards = 100 years.

will be reduced to 12 at 40 years, to 3 at 60 years, to 2 at 80 years, and to 1 at 100 years old. Though 38 standards are present on a certain area, only one reaches the end of the rotation, the others being cut from time to time, always leaving the best to reach the end of the rotation.

The actual number of standards per unit of area is governed by considerations for the underwood. If the standards are very numerous and give too much shade, the underwood will no longer thrive. In practice, a great variety of modifications have been introduced, according to whether the overwood or underwood is more favoured.

The *normal form* is that in which over- and underwood

receive equal attention. Here, the effect of the shade thrown by the overwood must always be carefully considered; generally, the shade should be evenly distributed over the area. It is always desirable that the bulk of the overwood should consist of species with thin crowns; in other words, of light demanding species.

Where *the overwood is favoured* the system approaches that of high forest. Here, the object is to produce as much timber as possible, and the shade of the standards would be so heavy, if evenly distributed, that the underwood could no longer thrive; hence, it is desirable to place the over- and underwood into alternate groups. This will enable the underwood to thrive on the areas allotted to it, while the standards will produce straighter and cleaner boles than under the normal form.

If *the underwood is favoured* the system approaches that of simple coppice. The standards are here so far apart that they will not, as a rule, produce long timber, unless they are brought together into groups here and there.

b. External Dangers.

These are small when compared with those peculiar to most other systems. To begin with, the overwood is, at any rate in the normal form, capable of protecting the underwood against frost and drought. Under any circumstances, such damage does not occur regularly and does not endanger the existence of the wood.

Storms do remarkably little damage in such woods. The younger classes of standards are protected by the older classes, and by the time they replace the latter, they have developed strong root systems, so that they can hold their own.

Insects are probably not more destructive than in the shelter-wood selection system, and less than in other systems, which is due to the variety of stocking, absence of cleared spaces or

loosened soil, and to the greater number of insect-eating birds which are found in such woods.

Game and mice, however, often do much damage.

c. Production of Wood.

It is smaller than under the high forest systems, but the difference is probably not very great. On the other hand, the system is specially adapted to the production of timber of all kinds and sizes. It affords opportunity for the individual development of the trees without endangering the factors of the locality to any great extent. In one point, however, it is inferior to high forest, inasmuch as the shape of the trees is not so good; they are shorter and less clear of branches in the lower part of the stem, unless the standards are placed into groups.

d. Effect upon the Factors of the Locality.

If treated properly, coppice with standards acts beneficially upon the factors of the locality; the laying bare of the soil at the end of every rotation of the underwood is only very partial and of short duration.

7. High Forest with Standards.

a. Origin and Character.

During the regeneration of a high forest, single trees or groups of trees are left standing, with the intention that they shall continue to increase in size for a further series of years. After the completion of the regeneration, such woods consist of a new crop and a number of standards scattered over it, either in single trees or in groups. The period during which the standards are retained differs from a few years to a whole or even two or more rotations.

b. External Dangers.

These are the same as those of the original system, with this addition, that the standards are liable to be thrown by

wind; hence, only wind firm species should be selected for standards, and the system should not be adopted at all in localities which are specially exposed to storms.

c. Production of Wood.

Under this system timber of very large dimensions is produced, such as cannot be grown under any ordinary high forest system, except under specially high rotations. If the standards are kept for less than a full rotation, much damage may be done to the young crop by their removal.

d. Effect upon the Factors of the Locality.

Directly, the effect is the same as that of the principal system. Indirectly, the system acts beneficially, as it obviates the adoption of very high rotations, where limited quantities of specially large timber are wanted.

8. Two-storied High Forest.

a. Origin and Character.

In the life of most woods, especially if they consist of light demanding species, a time arrives when the cover becomes interrupted, so that they can no longer preserve the factors of the locality. In the case of species where this time arrives at a comparatively early age, the second crop can be introduced, generally by sowing or planting, and allowed to grow up into high forest with and between the older crop, so that practically two distinct even aged woods exist on the same area, both high forest, the difference in age ranging from 15—60 years, according to species and circumstances; hence, the name of two-storied high forest. The two crops are cut over at the same time, when the whole process is re-commenced.

It is usual to thin the older crop heavily, either before or after the introduction of the second crop, by removing all diseased and badly shaped trees, leaving those which promise to develop into fine sound timber trees.

The older crop should, in all cases, consist of light demanding and the younger crop of shade bearing species, or else the latter is not likely to thrive.

b. External Dangers.

The older crop may be subject to damage by storms, but generally only for a short period. Damage by frost or drought in the case of the younger wood is generally excluded.

c. Production of Wood.

The system is well adapted for the production of large timber. During the first part of life, the trees comprising the upper storey grow up close together, developing height growth and clean boles; in after life, they are placed comparatively free and can rapidly increase in diameter.

The system yields also an early and substantial return in the way of heavy thinnings of the older wood.

d. Effect on the Factors of the Locality.

The system preserves the factors of the locality better than ordinary high forest, and deserves to be extensively followed in cases where it is desired to produce large timber of light demanding species, such as oak, ash, larch and Scotch pine.

9. High Forest with Soil-protection Wood.

When the leaf canopy in a high forest begins to become interrupted, an underwood is introduced for the protection of the soil. Such an underwood must be dense and not too old; hence, it must either be replanted from time to time, or, still better, coppiced periodically; it should consist of species which can stand the shade of the overwood, the latter consisting of thin crowned trees.

The effect on the factors of the locality is highly beneficial.

10. Forestry combined with the Growing of Field Crops.

The system of combining forestry with the cultivation of field crops is very old. Originally, it consisted in cutting down a

piece of forest, burning the wood, and using the land during one or more years for the production of field crops, and then allowing the forest to re-establish itself. In the course of time, the value of forest produce increased, and some order was brought into the system in European countries; the timber, instead of being burnt, was utilised, only the twigs and other inferior pieces being burnt. The following are the two principal forms now practised in Europe :—

a. Coppice combined with the Cultivation of Field Crops.

After each cutting over of the coppice wood the twigs and other valueless pieces of wood, together with turf, are burned. This process is effected either by distributing the brushwood evenly over the area, and letting the fire run over it, or by mixing it with turf, piling it up in heaps, and burning after the material has become sufficiently dry. In either case, the ashes are scattered, the soil is worked, and then used for one or two seasons for the production of field crops, which grow between the new coppice shoots.

It is said that, with proper care, the yield of forests so treated is not smaller than that of ordinary coppice woods. The returns from the field crops rarely do more than cover the outlay on account of labour, seed corn, etc.; hence, the system is now restricted to hilly parts, where a sufficient area of permanent fields is not available, and where additional occupation for the existing population is wanted, the forest lands not being of sufficiently good quality to make their conversion into permanent fields desirable.

The species of tree which is most commonly cultivated in this manner is the oak, and next to it the birch and hornbeam, while Scotch pine is frequently brought in after the cultivation of cereals has ceased, to help in covering the ground and increasing the revenue.

The cereals usually grown are :—

Buckwheat—*Polygonum Fagopyrum* and *tartaricum*, L., and rye—*Secale cereale hibernum*.

The buckwheat is sown immediately after the clearing and burning, say in June, and harvested 6 or 7 weeks afterwards. The rye is sown in autumn and reaped in the following summer, when the cultivation of field crops ceases. In some cases, the buckwheat and rye are sown together, the former being harvested in late summer of the first year, and the latter in the summer of the second year.

b. High Forest combined with the Cultivation of Field Crops.

After each cutting over of a high forest the soil is used for one or more years for the growth of field crops. The young forest crop is established, either at once, or after the growth of cereals has ceased, by sowing or planting in lines, or by sowing broadcast with the last crop of cereals. In some cases, the soil is burned over after the clearing of the forest crop, as described in the case of coppice.

In addition to buckwheat and rye, frequently oats, potatoes, etc., are grown.

c. Effect of the System on the Factors of the Locality.

The two variations of the system are subject to the ordinary disadvantages of the clear cutting system, and in addition the cultivation of field crops may exhaust the soil. Hence, they are only permissible where they are an absolute necessity, or on soil which can bear the strain of clear cutting and of the growing of field crops without becoming exhausted. Where a crop of spruce or Scotch pine is to be immediately followed by a new crop of the same species, the burning followed by the cultivation of a field crop can be recommended, wherever danger from insects is to be feared, the latter being destroyed or driven away by the burning.

The system is still extensively practised in India under a variety of names, as jhooming, dhya, kumri, taungya cultivation, etc. There, the whole of the old crop of wood is generally burned, so as to obtain as large a quantity of ashes as possible.

During the last 40 years, the practice has been taken advantage of in Burma to produce young teak woods. The clearings are made in comparatively useless forest, the cultivators undertaking to sow or plant teak between their field crops, for which they are paid at an agreed rate at the end of the first, second, or third year.

11. Forestry combined with Pasture.

Pasture lands are widely planted with forest trees, which yield a certain return, and also improve the value of the pasture by keeping out cold or dry winds and by affording shelter to the cattle. Broad-leaved species may also be lopped for cattle fodder.

The trees are established by planting strong seedling plants, which must be effectively protected against the cattle, until the crowns have grown beyond their reach. The trees may be placed in lines or groups.

12. Forestry combined with the Rearing of Game.

A forest, which is fenced and stocked with deer or other game, is called a preserve, or deer forest. The game, as a rule, interferes much with the production of trees, the latter being frequently the less important consideration.

High forest is usually preferable to coppice, because regeneration recurs only after longer intervals, and deer especially prefer coppice shoots to seedling plants; at the same time, coppice woods suit most kinds of game better than high forest. Species which produce food for the deer, as oak, chestnut, etc., should be represented in deer forests.

Young growth must be carefully fenced; planting is preferable to sowing, as the object should be to reduce the regeneration period to a minimum.

SECTION II.—CHOICE OF SYSTEM.

It has been shown in the last section that each silvicultural system has its special advantages and disadvantages, and that

their effects differ principally in respect of the production of wood, the power of resistance against external dangers, and the preservation of the factors of the locality. All these and many other matters must be considered in selecting the system which is best adapted to any special set of conditions. They may be brought under the following headings:—

(1.) Suitability of the system to the selected species.
(2.) The permanent preservation or even improvement of the factors of the locality.
(3.) Protection against external dangers.
(4.) Safety and simplicity of the method of regeneration.
(5.) Quantity and quality of the produce.
(6.) Intensity of management.
(7.) Existence or absence of forest rights.

1. Suitability of the System to the Selected Species.

This is a consideration of the first importance in all cases where it is desired to grow a particular species. In the first place, coniferous species cannot be treated as coppice woods; while several broad-leaved species, such as beech and birch, possess only a moderate reproductive power by shoots. In all such cases, only the high forest systems are indicated; beech and birch, at any rate, should not be grown in pure coppice woods. Again, light demanding species with thin crowns are but badly suited for ordinary simple high forest; they should be raised as standards in coppice with standards, or in two-storied high forest, or with a coppice underwood, or in mixture with shade bearing species. Such species are also difficult to raise under shelter-woods. On the other hand, tender shade bearers like beech and silver fir are better adapted to the shelter-wood systems than to the clear cutting system. Lastly, whenever a system involves two crops of different ages on the same area, the overwood must consist of a thin crowned, that is to say, light demanding species, and the underwood of a dense crowned or shade bearing species.

2. Preservation of the Factors of the Locality.

On general economic principles, forests should be worked and managed for a sustained yield, and not for a temporary high return; hence, it is necessary to select a system under which the factors of the locality are at least maintained, and if possible improved.

In the case of exceptionally good localities with a rich fresh soil and a favourable state of moisture and temperature of the air, any system can be adopted which answers to the other requirements of the case. On all localities of only middling quality, and still more so on poor localities with an unfavourable climate, the first consideration must be the preservation of the factors of the locality, or else a steady deterioration will set in, which may end in complete sterility. In such cases, clear cuttings must be avoided as much as possible, and every effort made to keep the area permanently stocked with a crop of trees; in other words, to regenerate under shelter-woods, so as to lead the old crop gradually over into a new crop. Unless this precaution is taken, the degree of moisture in the soil undergoes violent changes, which act most injuriously on production. The systems best adapted in such cases are the shelter-wood selection system, the other shelter-wood systems which produce uneven aged young woods, the shelter-wood uniform system, and coppice with standards.

3. Protection against External Dangers.

It should be the object of a good management to produce healthy woods, which are capable of resisting successfully the dangers to which they are exposed during life. Though species and method of regeneration are of principal importance in this respect, the system is also of some account.

Where the object is to counteract the eroding effects of water running down sloping ground, to prevent the occurrence of landslips, avalanches, or devastation through shifting sand, woods of uneven age must be the rule, such as are produced under the shelter-wood selection system or the group system.

Whether uneven aged woods suffer less from wind, snow, and ice than even aged woods is as yet an open question, though it will probably be decided in favour of the former.

In respect of frost, drought, and insects, the clear cutting system yields the worst results, the shelter-wood compartment system comes next, and then the systems which produce uneven aged woods, the shelter-wood selection system being best of all.

4. Safety and Simplicity of the Method of Regeneration.

Whether the one or other method of regeneration is the more suitable, depends on local conditions. In some cases artificial, in others natural regeneration is indicated. More especially, the importance of shelter-woods in the case of middling and inferior localities must never be overlooked, as well as in the case of those which are subject to external dangers. Again, in some cases natural regeneration is easy, in others difficult or almost impossible, and a selection must be made accordingly. Another point is that trees standing in an uneven aged wood produce, as a rule, more seed than those in an even aged wood. Finally, the system which acts most favourably in respect of the factors of the locality will also, as a rule, produce the most favourable germinating bed for the falling seed.

5. Quantity and Quality of Produce.

Woods yield timber, firewood, and a variety of minor produce. As regards wood, a distinction must be made between timber and firewood. Where only the latter is wanted, that system is preferable which yields the largest volume or greatest weight of produce within a certain space of time. Where the objects of management centre in the production of timber, other considerations prevail. Such production, if the timber is to be of any size, takes long periods of time, and it demands a continuous energetic action of the locality. More especially, a continuously even degree of moisture in the soil has to be aimed at. Next, the proper

amount of light must be given to each individual tree, in other words, a sufficiently large and well-developed crown. These considerations lead to the following conclusions :—

(*a.*) On fertile soil, with a sufficient degree of moisture, in the case of shade bearing species, and under moderately high rotations, the even aged systems yield satisfactory results, and their selection is justified.

(*b.*) On less fertile soils, which necessitate a careful husbanding of the factors of production, in the case of some of the species being light demanding, or treated under a high rotation, the systems of uneven aged woods are desirable.

The former produce principally long and clean timber, the latter greater girth.

In many cases, the objects of management favour the production of minor produce, and the system must be selected accordingly. Where tanning bark of oak is wanted, the system of coppice is in its place. Osier beds require to be planted on cleared land. The growth of field crops also is only practicable under the system of clear cutting; at the outside, only a few standards may be left on the ground. Where grass and grazing is wanted, the woods should be even aged, which means a short regeneration period; or else the cattle will damage the young trees.

6. Intensity of Management.

The more valuable the returns of the forest are, the more intense, or careful and detailed should be the system of management.

The capital invested in a forest differs considerably under different systems, it being composed of the value of the land plus the value of the growing stock, apart from buildings, etc., which would be required under any system. Hence, high forest requires a much larger capital than coppice, and may yield a smaller interest on the invested capital than the latter.

Artificial regeneration requires a periodical outlay of cash for sowing or planting, while natural regeneration can be effected without such outlay, though it may involve a considerable loss of time.

The transport of the material is considerably cheaper in even aged than in uneven aged woods, because in the former case the operations are more concentrated. The same holds good as regards supervision.

The shelter-wood systems require more skilled labour than the clear cutting systems. They also make much greater demands on the intelligence and industry of the manager, because they require higher skill and more constant supervision.

7. Existence or Absence of Rights.

In many cases, the existence of rights necessitates the selection of a particular system. For instance, where large timber has to be provided to right-holders, the coppice system would be inadmissible.

8. Summary.

Every silvicultural system has its advantages and disadvantages, and it is necessary to ascertain in every case, whether the balance of the two tends towards the one or other system. The forester must decide which system meets most completely the objects of the proprietor. *From a silvicultural point of view,* the first point for consideration is the general suitability of the system, and next the continued preservation and, if possible, improvement of the factors of the locality; temporary, or immediate, financial considerations should only prevail in so far as they do not interfere with the two former considerations.

PART II.

FORMATION AND REGENERATION OF WOODS.

FORMATION AND REGENERATION OF WOODS.

The formation of a wood comprises all measures having for their object the production of a new crop of trees. Such a crop can spring up from seed, slips, layers, pieces of roots, or from stool shoots and root suckers. In some cases the formation of a new crop is the result of the spontaneous action of Nature, in which case the forester speaks of *natural formation* or *regeneration;* in others, the seeds or young plants are brought on to the land by the action of man, when the process is called *artificial formation.* A further distinction must be made as regards the special kind of material employed in the formation of a wood. Again, two or more methods of formation may be combined. And again, a wood may be composed of a mixture of two or more species. Finally, certain preliminary works may have to be carried out, before the formation of a wood can be commenced. Accordingly, this part has been divided into the following chapters :—

Chapter I. Preliminary Works.
,, II. Artificial Formation of Woods.
,, III. Natural Regeneration of Woods.
,, IV. Formation of Mixed Woods.
,, V. Choice of Method of Formation.

CHAPTER I.

PRELIMINARY WORKS.

Before a wood can be formed certain preliminary matters must be attended to. These will be indicated in the following three sections :—

Section I.—Choice of species.
,, II.—Fencing.
,, III.—Reclamation of the soil.

SECTION I. CHOICE OF SPECIES.

The success of forestry depends, in the first place, upon a judicious selection of the species of tree which is to be grown under a given set of conditions. A full consideration of this matter is of great importance, because mistakes made in the selection of species cannot, as a rule, be rectified until after a considerable lapse of time. Most indigenous species thrive almost equally well on ordinary soils for a series of years, while those unsuited for a particular locality commence falling off only after perhaps 20, 30 or even more years.

The full success of a species depends on many things, amongst which the following deserve special attention :—

(1.) Suitability for the objects of management.
(2.) Adaptability to the desired silvicultural system.
(3.) Exposure to damage by external causes.
(4.) Suitability of species for the locality.
To which may be added,
(5.) Desirability, or otherwise, of a periodical change of species.

1. Suitability of the Species for the Objects of Management.

The varying objects of management have been indicated on page 1. Whatever they may be in any special case, the species must be selected so as to do them full justice.

If the object is to grow produce of a definite description, the species must be capable of yielding it; it would be useless to grow yew for hop poles, or poplar for naval construction. Where the objects of management are governed, or influenced, by existing forest rights demanding timber or firewood of a particular species, that tree must be grown. If, on the other hand, third persons are entitled to trees of certain species, should they happen to appear on the area, the owner would not voluntarily cultivate them.

Where the object is to produce the greatest possible quantity of material per unit of area, that species must be selected which produces the highest average annual increment.

In gauging the financial desirability of a species, the quantity and quality of the produce, as well as the expense of rearing it, must be taken into account. In some cases only certain species are saleable, while others are without value. Again, some species produce a much higher percentage of timber as compared with firewood, than others.

Species with a thin crown are indifferently adapted for wind breaks, whereas they may be specially suited for nurses over a tender crop, or as standards over coppice.

The above instances will suffice to show that the number of species which may be desirable in any given case is narrowed down by the objects of management.

2. Adaptability of the Species to the desired Silvicultural System.

All species of trees can be treated as high forest, but only a certain number as coppice woods. The conifers of temperate Europe either do not coppice at all, or very indifferently; even some of the broad leaved species do not yield satisfactory

results. Shade bearing species are not desirable as standards in coppice with standards. Species which are tender during youth should be grown under a shelter-wood system, and *vice versâ*. A selection of species must be made accordingly.

3. Exposure of the Species to Damage by External Causes.

The selection of species to be planted is further narrowed by the degree to which they are exposed to injury by external causes, as fire, frost, draught, cold winds, strong gales, insects and fungi. Conifers, for instance, are more exposed to damage by fire than broad leaved species; larch and silver fir suffer much from canker; spruce is liable to be thrown by wind; beech and silver fir are frost tender, while Scotch pine and birch are frost hardy; Scotch pine and spruce are more subject to damage by insects than any other European species, etc. All these matters influence the choice of species under a given set of conditions.

4. Suitability of the Species for the Locality.

From the point of view of Political Economy, the improvement, or at any rate the maintenance, of the yield capacity of the locality is the most important consideration. Whether the owner of a forest be the State or a private person, he will find a system of management recognising that principle to be the most profitable in the long run. Hence, it must be the forester's endeavour to grow species, which not only suit the locality but also tend to improve it.

In the first place, the *quality* of the locality must be carefully ascertained, so as to avoid growing a species which has no chance of thriving on it. This task is by no means an easy one, because the effects of some of the factors of the locality on tree growth are as yet imperfectly understood. The climatic factors are of special importance; hence, the effects of the geographical position, altitude, aspect, gradient, contour, and surroundings of the locality upon the temperature, degree of moisture, and air currents must be carefully considered.

The soil and, if necessary, the subsoil as well must be examined as to depth, degree of porosity and moisture, composition and admixture of humus. The development of any trees already growing on the locality, or in its vicinity, should be carefully studied. An investigation of this kind will generally indicate what species are capable of thriving on a locality; it should, however, not be overlooked that any species found growing naturally on the area are not always those best adapted for it, because their presence may depend on circumstances other than a general suitability of soil and climate; for instance, a shade bearing species may have ousted a light demanding one, or a greater power of reproduction may have enabled one species to drive out another possessed of less energy in that respect.

As long as the factors of the locality are fairly the same over the whole area, the latter may be treated in a uniform manner, but the occurrence of decided differences may necessitate the selection of different species for different parts. Any attempt at uniformity, in spite of such differences, may lead to a serious loss in returns.

In order to provide for a continuous preservation of the fertility of the locality, it is necessary to select species which give sufficient shelter to the soil and a good supply of humus, or, at any rate, to mix such species in sufficient numbers with those which do not shelter the soil. This rule can only be disregarded in thoroughly favourable localities. Under these circumstances, species with dense crowns must receive special attention in making a selection for middling and inferior localities; in addition, interference with the fertility of the soil, such as the removal of leaf mould, excessive grazing, faulty treatment, etc., must be carefully avoided. Above all, personal fancy on the part of the forester for a particular species must be set aside.

Not unfrequently, several species are found to be equally well adapted for a locality. In such cases, other considerations must decide which shall be grown, or whether a mixed wood is preferable.

Owing to the great variety of the factors of the locality, the task of selection is frequently rendered difficult. On fertile, deep, fresh soil almost any species will thrive. Again, where the locality has such a decided character that only one or two species are admissible, the choice is easy enough; for instance, deep dry sand points to the cultivation of the Scotch or Weymouth pine, wet soil to that of the alder. Where, however, the fertility of the soil has deteriorated, for instance by the continual removal of litter, or where damage by fire, frost, drought, snow, storms, and insects may be apprehended, it is often difficult to select the most suitable species.

Frequently, the factors of the locality do not exactly correspond with the requirements of any species, so that the power of accommodation becomes an important element. This power in the case of some species is confined within narrow limits, while others can adapt themselves to all sorts of conditions. For instance, Scotch pine and birch are very accommodating as regards soil and climate; spruce, beech, and silver fir are less accommodating, and still less so are the maples, alder and ash. Sometimes, the power of accommodation depends chiefly on one factor; if that is not present the species will not thrive. Taking for instance the temperature, sweet chestnut and common elm are exacting, while Scotch pine is the reverse. Oak and alder require particular degrees of moisture in the soil, while birch and Scotch pine are not particular. Spruce prefers moist air, etc.

5. Change of the Species.

The question deserves to be mentioned here, whether in silviculture, at the end of successive rotations, a change of species is advisable, or not. Change of crops is practised in agriculture, because different species make different demands on the soil. By changing the crop annually, more time is given for the accumulation of the substances which a particular species may require. In the same way it has been suggested that better results might be obtained in silviculture by a

change of species, especially as certain phenomena seemed to support such a view. It has been observed, for instance, that coniferous trees here and there supplant broad leaved species, that spruce frequently usurps the place of silver fir, and birch that of Scotch pine, or that exacting species no longer thrive in certain localities.

On a close investigation, such a theory will be found untenable except on poor soils. Timber trees take comparatively small quantities of mineral substances from the soil, if the leaf mould be not removed, in fact, only about one-twelfth of the total quantity required by field crops, and about one-twentieth of the rarer substances ;* hence, all except poor soils can go on providing the necessary quantity of mineral matter for any length of time. The trees protect the soil by their foliage, whilst the fallen leaves give a substantial amount of organic matter, in addition to the inorganic materials previously taken from the soil. This amount may be so considerable that an increase of fertility may actually be produced. If, nevertheless, in some cases a reduction of the fertility should be observed, it will be due to insufficient shelter afforded by trees with thin crowns, to heavy removals of litter, faulty treatment, fires or other causes.

The fact that one species sometimes supplants another is generally due to its greater reproductive power, or its greater resisting power against external influences. For instance, the felling of a spruce or Scotch pine wood may be followed by the appearance of large numbers of insects, which breed in the stools of the trees left in the ground, and destroy any young crop of these species which may spring up; other species not subject to such attacks may then occupy the ground, if allowed to do so.

As a rule, in silviculture a change of species is called for only in special cases, such as the following :—

(1.) When the original species has, on general grounds, been found unsuited for the locality.

* See page 40.

(2.) When an inferior species is to be replaced by a more valuable one.

(3.) When the fertility of the soil, in consequence of faulty treatment, heavy removal of litter, etc., has deteriorated, so that the original species will no longer thrive on it, and must give way to one less exacting.

(4.) When a temporary shelter-wood (nurses) is required for a tender species.

(5.) When the object is to extend the growth of one species uniformly over a certain area.

SECTION II.—FENCING.

Fencing is used for nurseries and woods. Whether it is required for the latter depends on the extent to which a particular species is exposed to attacks by cattle or game. Erecting fences is ordinarily one of the heaviest items of expense in the formation of woods, and it is essential to select in each case that kind which, while meeting the necessary requirements, involves a minimum outlay.

The number of different kinds of fences, which are in use or have been suggested, is very great. It is not intended to describe these here in detail, as a practical knowledge can only be obtained out of doors. It will suffice to enumerate the principal kinds, and to give illustrations of a few which seem specially adapted for silvicultural purposes.

1. Hedges.

Hedges are formed of a great variety of trees and shrubs, of which, for temperate Europe, the following may be mentioned: Hawthorn, blackthorn, beech, furze, holly, laurel, yew, box, privet, barberry, hornbeam, birch, elder, spruce and silver fir. For silvicultural purposes, hawthorn, beech, hornbeam and spruce are perhaps most to be recommended. Several years will elapse, however, before they can efficiently protect an area

against cattle or game; hence, they must either be planted beforehand, or augmented by a temporary fence of some other kind.

Fig. 10 represents a cross-section of a wedge-shaped thorn hedge (after Brown).

Fig. 11 shows a longitudinal section of a thorn hedge (after Heyer); each plant has been coppiced near the ground; of the shoots which appeared, two were left on each stool,

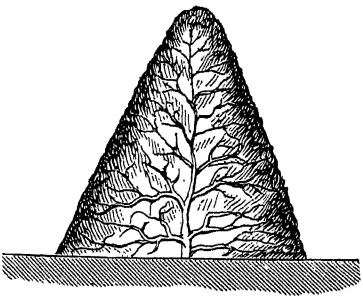
Fig. 10.

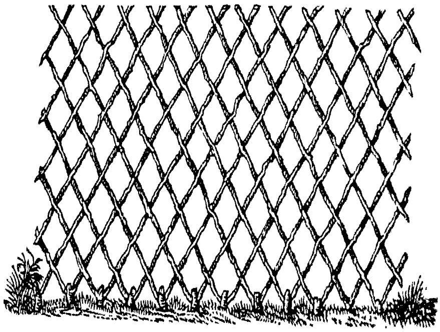
Fig. 11.

trained to opposite sides and interlaced. Such a hedge can be made to keep out hares and rabbits.

Living hedges are, in forestry, only used for nurseries or along roads leading to pastures.

2. Walls.

These may be dry stone walls, or they may be constructed with mortar. The former are liable to fall, and the latter are very expensive. Walls generally interfere with the free circulation of air; in some cases, this may be desirable for the purpose of protecting tender plants against cold air currents.

Turf dykes are walls constructed of turf and can replace stone walls, where turf is abundant and stones are rare; at the same time, they are of a perishable nature. In the accompanying Fig. 12 (after Brown), the natural surface line

is represented by *a*, *a*, *a*, *a*, while *b*, *b* are the places where the turf has been excavated, and *c*, *c*, the dyke consisting of successive layers of turf.

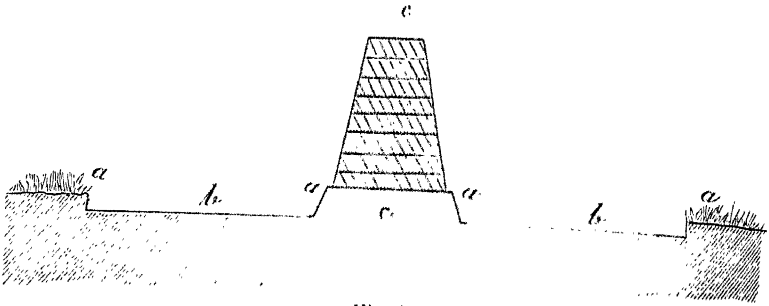

Fig. 12.

3. Wooden Palings.

There is an endless variety of wooden palings.

Fig. 13 shows a wooden fence, affording protection against rabbits on one half of the diagram. It suffers under the

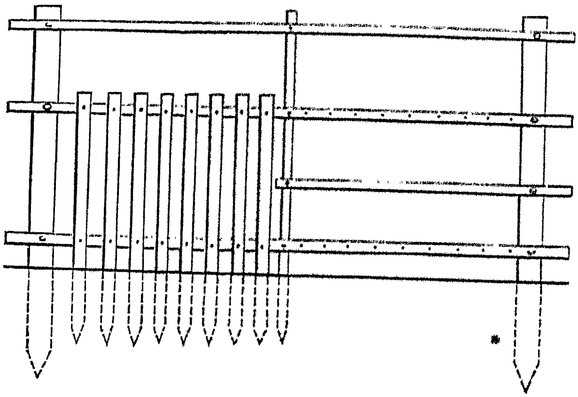

Fig. 13.

disadvantage that all the upright spars must be driven into the ground, which causes them to rot. To reduce this danger, the inserted part should be tarred or creosoted. It is far better to replace the short spars by wire netting.

Frequently, wood fences are made in sections, so that they can be carried from one place to another.

4. Ditches.

Ditches for keeping out animals should be constructed with a perpendicular wall (*a*) on the inside and a gentle slope (*b*) outwards (Fig. 14); sometimes the perpendicular side is faced by a stone wall (*c*) to prevent its falling in. On the whole, ditches are expensive, if constructed so as to be lasting; hence, in the majority of cases they are only used as an auxiliary to other fences, for instance a wooden paling or a wire fence (*d*).

5. Wire Fences.

Here again, a great many varieties have been introduced,

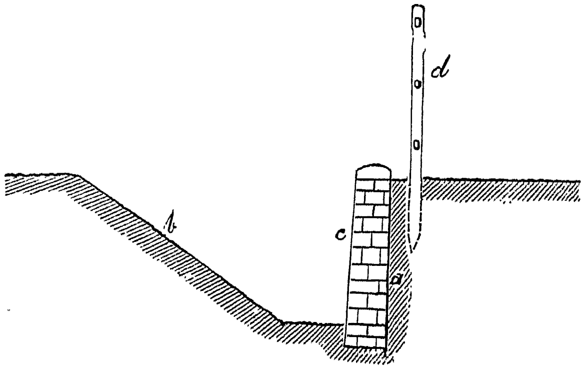

Fig. 14.

some having iron standards and others wooden supports. In the case of permanent nurseries, iron standards may be desirable, but in fencing woods, which only require protection for a limited number of years while under regeneration, wooden supports will, in the majority of cases, be found cheaper. On the whole, for silvicultural purposes wire fences with wooden supports are probably more suitable than any other kind.

Fig. 15 represents a fence consisting of wooden supports, with six wires so arranged as to keep out horned cattle, horses and sheep; height 4 feet. *a - - - a* shows the surface of the soil; *b* and *c* the two end or straining posts of a section, which should not be further apart than 600 feet; *d*, *d* represent

intermediate thinner posts, placed from 5 to 10 feet apart; *b* and *c* have each six holes bored into them. At *b* the ends of the wires are passed through these holes, bent round the post, and fastened securely to the wires at *e*. At the other straining post, *c*, the wires are strained and fastened by various contrivances, one of which is shown in the illustration. It

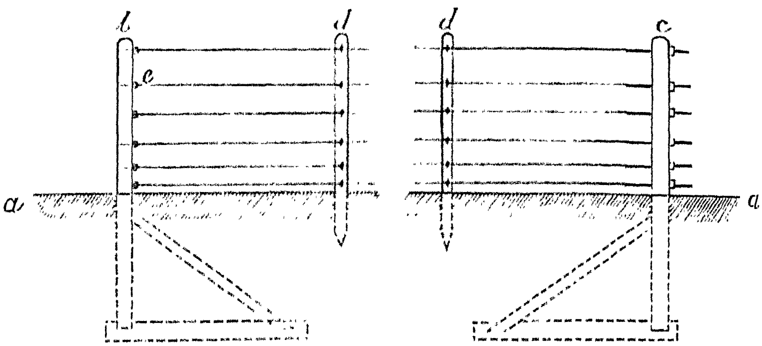

Fig. 15.

consists of a screwed eye-bolt not less than 12 inches long. The end of the wire is fastened to the eye of the bolt (Fig. 16, *a*), and the latter passed through the hole in the straining post. On the other side a nut, *b*, is screwed on after first inserting a plate or washer, *c*, to prevent the nut from cutting into the wood. By turning the nut sufficiently, the wire becomes

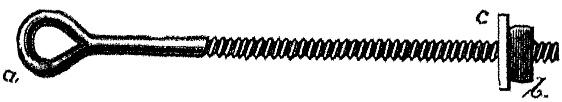

Fig. 16.

strained. The wires are fastened to the intermediate posts by staples (Fig. 17). These are driven half-way into the posts and the wires passed through, before the straining commences. They are driven home when the straining has been completed.

Fig. 18 shows a cast-iron straining bracket fastened to a

wooden pillar; this is worked with a key. It is used instead of the eye-bolt.

Where rabbits or hares are to be kept out, wire netting may be added to the lower part of the fence.

The cost of the materials in England may be estimated as follows:—

Wire, imperial standard wire gauge, No. 8, about one shilling per 100 feet; galvanised, $\frac{1}{3}$ more. Straining bolts, 12 inches long, $\frac{5}{8}$ inch diameter, with nut and washer, tenpence each. Straining brackets (Fig. 18), tenpence each.

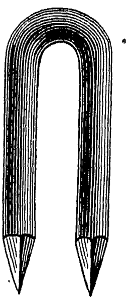

Fig. 17.

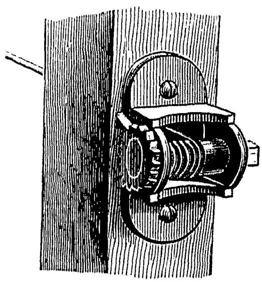

Fig. 18.

Steel staples, per 1,000, 9*s.*; galvanised, $\frac{1}{3}$ more. Thus, the iron materials come to about 3*d.* a yard, or 4*d.* if galvanised wire and staples are used. The costs of the posts and of labour depends on lòcal circumstances.

For nurseries, iron fences may be used, to which wire netting may be added, if necessary. Fig. 19 represents such a fence. It is 4 feet high, the pillars are $2\frac{1}{2}$ feet in the ground, and the fence is strong enough to keep out horned cattle, sheep, goats, hares, and rabbits. The straining pillars, *a*, are so arranged as to strain the wires on both sides; they are usually, in this fence, placed 220 yards apart. The standards, *b*, are tee-irons, $1\frac{1}{2}'' \times 1\frac{1}{2}'' \times \frac{3}{16}''$, placed 12 feet apart. The top wire is galvanised barb No. 4, the three lower wires No. 6 galvanised strand. The netting is $1\frac{1}{2}$ inches mesh, medium quality; it reaches $3\frac{1}{2}$ feet above ground, and is

pegged down 6 inches along the surface outside, to prevent rabbits burrowing under it. This fence is offered in the London market for about 1*s.* 5*d.* a yard.*

6. Combinations.

Frequently, two kinds of fences are combined. More particularly, wooden palings or wire fences or even turf dykes and

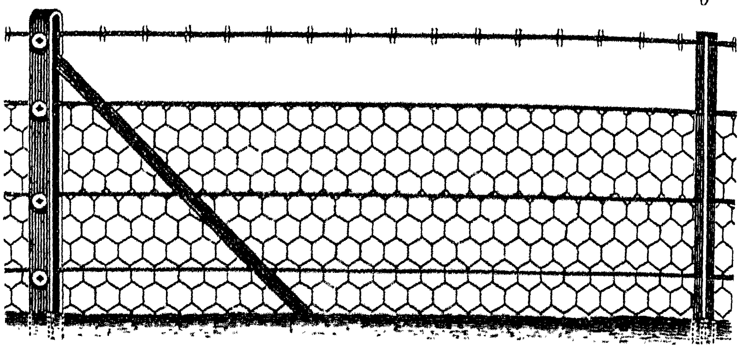

Fig. 19.

walls may be added to ditches, or walls and turf dykes may carry a wire fence or a wooden paling (see Fig. 14).

7. Choice of Fence.

The choice of fence depends chiefly on:

(1.) The time during which it is required.

(2.) The species of animal to be kept out.

If an area is to be protected permanently, or at any rate during a considerable period of time, the fence should be of a substantial nature, such as a living hedge, wire fence with iron standards, or stone wall. For a limited number of years, wooden palings, a wire fence with rough wooden standards against cattle, or wire netting only against rabbits, will be cheaper. The latter can be erected for five to seven pence per running yard, according to circumstances.

Protection may be provided against horned cattle, horses,

* By the Iron Wire, Wire Rope, and Fencing Company, Westminster.

sheep, goats, and deer by any of the above-mentioned fences. Where hares and rabbits are to be excluded as well, wire fences, and often also hedges and wooden palings, require the addition of wire netting, or a similarly effective arrangement. In the case of rabbits and hares only, wire netting, with cheap standards, suffices; the wire netting must go from 6 to 12 inches below the surface; a still better arrangement is to lay it flat on the surface on the outside for 6 to 12 inches and cover it with soil or turf.

Against ordinary cattle, a height of 4 feet is sufficient, but against deer the fence should be 6 and even 7 feet high. For the latter purpose, where protection against rabbits is not wanted, strong wire netting with about 4 inches mesh has of late come into use.

It should always be remembered that the larger the area to be fenced, the smaller will be the cost per acre.

SECTION III.—RECLAMATION OF THE SOIL.

Soil may be called fertile for silvicultural purposes, if it possess sufficient depth, a suitable degree of porosity and moisture, and a suitable chemical composition. Forest soil, if undisturbed, will in most cases maintain, or even acquire, those physical conditions which render regular artificial tillage unnecessary. Immediately before and during the formation of a wood, however, certain things may have to be done to render the soil fit for the growth of trees. These measures may be divided into the following two groups:—

(*a*.) Reclamation of soil unfit for the growth of trees.

(*b*.) Tillage of the soil concurrent with the formation of a wood.

The latter will be dealt with in connection with the various methods of starting a wood. Group (*a*) includes the following measures:—

(1.) Treatment of an impermeable substratum.

(2.) Treatment of swampy ground generally.

(3.) Irrigation of arid land.

(4.) Treatment of excessive layers of vegetable matter.

(5.) Fixation of shifting sand.

(6.) Fixation of unstable soil on slopes.

It would require a volume to itself to deal exhaustively with these matters; hence, in this place only a few short remarks can be made on the more important points. Those who require more detailed information, will find it in Volume IV. of this Manual and in special works on the several subjects.

1. Treatment of an Impermeable Substratum.

Impermeable strata in the soil consist, in some cases, of an accumulation of clay, which has by degrees been washed out of the surface layers and deposited at a certain depth; in other cases, sand or gravel has been converted into a hard rock-like mass by the addition of organic matter, clay, or oxide of iron. Where heather prevails, the decomposition of the dead parts proceeds at a slow rate, so that an excess of humic acid is produced; the useful elements of the soil are carried below, a white, washed-out sand remains, and below it an impermeable stratum is formed. Such a stratum is frequently called a *pan*. It may be found at varying depths below the surface; if at a depth of 4 feet or more, it does not, as a rule, interfere with the growth of forest trees, except perhaps on arid unirrigated ground, but if it occurs nearer the surface it may produce the following injurious effects:—

(*a.*) Interference with the development of a proper root system, followed by small height growth and liability of the trees to be thrown by strong winds.

(*b.*) Interference with the movement of water in the soil, preventing its penetration into the subsoil during wet weather, and its ascent during dry weather; in other words, it may render the soil too wet at one time and too dry at another.

The remedy is to break through the impermeable stratum, so as to connect the upper and lower permeable layers of the

soil. According to the nature of the pan and its depth below the surface, one of the following methods of treatment must be adopted :—

(*a.*) Deep ploughing.
(*b.*) Trenching.
(*c.*) Raising the surface level.
(*d.*) Addition of lime to the surface soil.

If the lowest part of the pan is not deeper than 18 inches below the surface and not too hard, ploughing may be adopted; the pan, being brought to the surface and exposed to the atmosphere, soon disintegrates. Pans, situated at a greater depth than 18 inches, must be broken through by trenching with spade, hoe, pick, or crowbar. In either case, the operation is expensive; hence, it is usual to treat only part of the area, in strips, patches, or holes. Strips may be 2 to 3 feet broad, separated by unbroken ground 4 to 6 feet in breadth, so that the actual work is restricted to about one-third of the area. Patches may be of various sizes, down to holes about 12 inches square.

If the pan is very thick and goes to a greater depth than 3 feet, it may be cheaper to raise a portion of the land, by cutting ditches at intervals and placing the excavated earth on the intermediate strips, thus providing the latter with a depth of soil sufficient for the production of trees.

The treatment of impermeable strata is always an expensive matter, so much so in many cases that the utilisation of the area becomes altogether unprofitable. In some cases, the expense may be avoided by planting a shallow rooted species and being satisfied with moderate returns.

When the formation of the pan is due to an excess of humic acid, as on heather land, lime may be given, which binds the excessive quantity of the acid.

2. Treatment of Swampy Ground generally.

Each species thrives best with a definite degree of moisture in the soil at all times of the year. That degree differs

considerably in the case of the several forest trees; while some like moist and even wet soil, others will not flourish in such localities, and none of them in stagnant water. It follows that an excess of moisture, over and above what is suitable for a given species, must be removed before a wood is started. The method of doing this depends on the cause of the excess of moisture.

A locality becomes swampy if it receives more water than can be disposed of by evaporation, filtering into the subsoil, or surface drainage. An excess of water may be due to excessive rainfall, inundation, underground currents, or springs; in the first two cases, the swampiness may be only temporary. The natural draining away of the excess water may be impeded by an insufficient local gradient, by an impermeable soil, or by both combined.

Before removing the surplus water from a swampy piece of ground, the expense and the effect of drainage on the surrounding lands should be carefully considered. The cost is, as a rule, considerable and sometimes prohibitive; draining a swamp may, especially in a hilly country, seriously reduce the necessary degree of moisture of adjoining areas, the continuous flow of water in the ordinary water channels, even the amount of rain and dew in the neighbourhood, or lower the level of underground water. Existing woods, which have become accustomed to a certain degree of moisture, may thus be seriously injured.*

If, after full consideration, it has been decided to remove the excess water, this can be done, either by diverting the water before it reaches the swampy ground, or by draining the latter.

a. Diversion of Excess Water.

This is done by embankments in the case of inundation water coming from rivers in low lands, or by ditches in the

* It is believed that some of the elms in the Long Walk, Windsor Park, died in consequence of drainage carried out some time ago; after these drains had, in consequence, been blocked again, the remaining trees recovered.

case of spring water or surface drainage coming from higher ground.

Inundation water moving over the surface of the land may be kept out of a certain locality by a surface embankment; if the water moves underground, it can only be stopped by a substantial underground embankment, such as a stone or concrete wall.

Spring water and surface drainage in hilly ground is caught and diverted, by running a ditch of suitable dimensions along the slope of the hill just above the swampy ground. The ditch intercepts the water and leads it past the swamp.

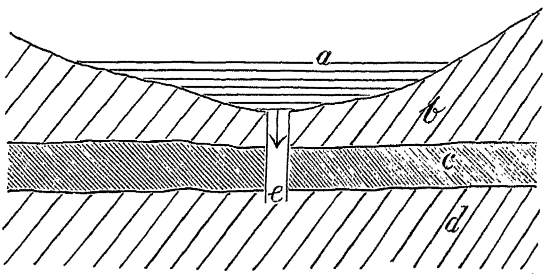

Fig. 20.

In cases where the spring is situated in the swampy ground itself, only draining can meet the evil.

b. Draining.

A swamp may be drained :—

(1.) By increasing the gradient (or width) of existing water-courses. This is practicable when the latter pursue a winding course; in such a case the course may be straightened, so as to increase the velocity of the current. The method is only occasionally applicable.

(2.) By breaking through an impermeable stratum in the soil, so that the water can filter into the subsoil (Fig. 20). Here, *a* represents the water, *b* and *d* permeable strata, and *c* an impermeable stratum; *e* the channel leading from the swamp to the lower permeable stratum.

(3.) By constructing a series of ditches, or laying down a series of drainage pipes. The latter are rarely used in forestry, because they are expensive and liable to be choked by the roots of the trees. For the same reasons, covered ditches are only rarely employed. The method usually followed consists in the construction of a series of open ditches, because they are comparatively cheap, whilst setting aside a portion of the area for ditches does not reduce the returns.

There may be three kinds of ditches:

(1.) The collecting ditches, or feeders;

(2.) The connecting ditches, or leaders;

(3.) The main drain.

See Fig. 21.

The feeders receive the water from the soil and conduct it to the leaders, whence it is taken into the main drain. In some cases, the feeders fall directly into the main drain.

The *first step* in proceeding to drain an area is to take levels, so as to ascertain accurately the fall of the locality; if the area is of some extent, a map showing contour lines should be prepared. Unless this is done, mistakes are likely to occur in laying out the system of drains.

The *second step* is to lay out the main drain, if possible along the natural line of drainage; in other words, along the lowest part of the area. According to the natural fall of the land, the gradient of the main drain may have to be increased by cuttings; in other cases, it must be reduced by giving it a winding course, so as to secure a suitable fall; or terraces may be constructed.

The *third step* is to lay out a system of feeders, more or less parallel to each other, at a suitable angle with the general slope of the country, and to connect them at an acute angle with the main drain, either directly or through a leader, which is similarly connected with the main drain.

In laying out such a system of drains, the gradient, depth, shape, and distance from each other require careful consideration.

The *gradient,* or fall, should be such that the water is carried away with sufficient rapidity, without causing injury to the base and sides of the drains by the scouring action of

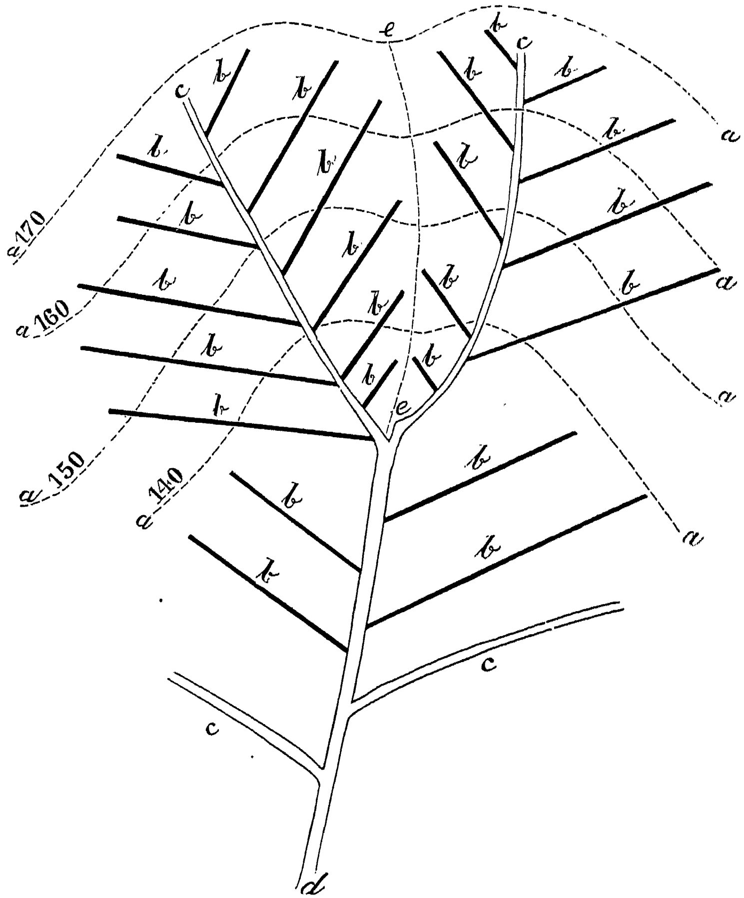

Fig. 21.

a, *a*. Contour lines.
e, *e*. Water parting.
b. Feeders.
c. Leaders.
d. Main drain.

(The figures 170, 160, 150, and 140 give the elevation in feet above sea level.)

the water. Where the natural gradient of the ground is insufficient, the base of the drain must be sunk until the necessary fall has been obtained. Where it is too great, the

drains must pursue a winding or zig-zag course, so as to reduce the fall; or the base and sides of the drains must be protected by a facing of stone, or fascines; in some cases the base may be terraced.

The maximum gradient which is admissible depends on the nature of the soil. Where the latter is of middling consistency an average fall of 1 per cent. would probably be indicated; on firm soil it may be greater, on loose soil smaller.

The *depth* of the feeders depends on the depth to which it

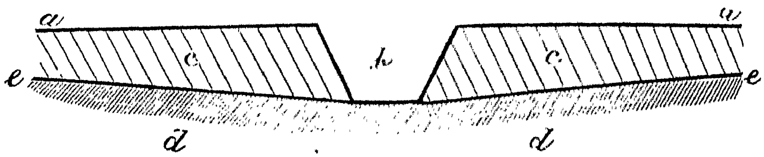

Fig. 22.

a, *a*. Natural level of ground.
b. Feeder, four feet deep.
c, *c*. Layers of soil actually drained.
d, *d*. Layers of soil not drained.
a to e. About three feet.

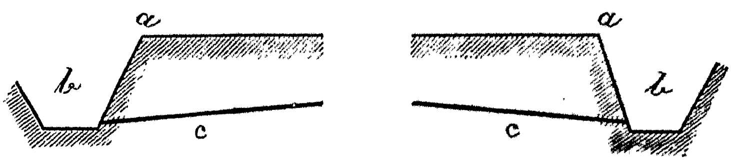

Fig. 23.

a, *a*. Natural level of ground.
b, *b*. Leaders (five feet deep), or main drains.
c. *c*. Feeders. Depth at upper end, 3 ft. 6 in., at lower end, 4 ft. 6 in.

(In these diagrams the height is exaggerated.)

is intended to drain the land; the former must be somewhat greater than the latter. The depth to which the soil requires draining may vary from 18 inches to 3 feet, according to the species to be grown. Ash, hornbeam, and elm can do with 18 inches, while Scotch pine, beech and silver fir, prefer soil which is drained to a depth of 3 feet.

Figs. 22 and 23 illustrate the comparative depth to which a locality is drained, and that of the feeders and leaders.

The *shape* of the drains depends on the fall and on the

nature of the soil; the greater the cohesion of the latter, the steeper may be the slopes of the sides. In the case of peat, the sides may be almost perpendicular, in stiff loam they should form an angle of about 45 degrees, and they must become more and more slanting, as the proportion of sand in the soil increases. The base of the ditch should be at least as broad as the spade which is used in making and afterwards cleaning it. For the rest, the width of the drain depends on the body of water which has to be carried away.

The *distance* between two successive feeders depends on the permeability of the soil, the depth of the ditches, the depth

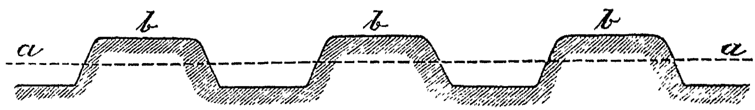

Fig. 24.
a—a. Natural level of swampy ground.
b, b, b. Ridges on which the trees are to be planted.

to which the land is to be drained, and the general fall of the locality; it will usually range between 30 and 100 feet.

c. Raising the Level of Part of the Ground.

If it is undesirable or impracticable to drain a swampy area, and, if the water is of moderate depth, it may nevertheless be rendered useful, by excavating part of it and using the soil so obtained to raise the level of the rest to a sufficient height, so as to render the cultivation of trees practicable. In such cases, the raised parts generally form parallel ridges, as indicated in Fig. 24. Such works are expensive, and only species which stand a good deal of moisture can be grown.

3. Irrigation of Arid Land.

In temperate Europe, irrigation is employed only in nurseries, but in more southern, tropical, and arid countries extensive areas are artificially irrigated for the growth of forest trees. The details of irrigation must be studied from

a special work on the subject.* In a general way, irrigation may be described as the reverse of draining; thus in Fig. 21 (page 141), *d* would represent the main supply channel, situated in the highest part of the area, *c*, *c*, *c* the leaders, and *b*, *b*, *b* the distributing trenches. The watering of the land may be caused by overflow from the trenches, or by percolation; in the latter case, the trenches would only be just filled, and no more.

Where extensive areas are to be irrigated, the channels and trenches must be carefully laid out, with a suitable fall, so as to prevent the bursting of the channels and the silting up of the trenches.

4. Treatment of Excessive Accumulations of Vegetable Matter.

Cases occur in which accumulations of vegetable matter have to be disposed of, before the formation of a wood can be taken in hand. Such accumulations may be objectionable, because they are so thick that the seedlings cannot reach the mineral soil within a reasonable space of time, and run the risk of drying up; or they may have become acid, or bituminous; again, they may be accompanied by swampiness, or be liable to dry up too quickly.

The following cases specially interest the forester:

a. Peat Bogs.

To render a peat bog fit for the growth of timber trees, one or all of the following operations must be carried out:—

(1.) Draining.

(2.) Removal of at least a portion of the peat.

(3.) Mixing the peat with the mineral soil.

The draining is done in the manner described above; it is, however, desirable to do this gradually, so that the layers of peat may dry by degrees, to prevent the formation of extensive cracks. The feeders should at first be of moderate

* For instance, "The Roorkee Treatise on Civil Engineering in India," Vol. ii., Section x

depth, and gradually deepened, until the mineral soil is reached.

When the layer of peat is shallow, it can, after draining, be mixed with the mineral soil below it, and thus rendered fit for the growth of trees; a good plan is to grow one or two field crops on the area, before the trees are planted.

If the layer of peat is deep, 3 feet and more, the upper portion must be removed, and only the remainder mixed with the mineral soil. The cut peat may be used as fuel, but if not so required, it may be cheaper to burn the upper layers *in situ* when sufficiently dried by draining, the ashes being mixed with the soil.

b. Accumulation of Raw Humus.

This may consist of an accumulation of leaves, needles, weeds, moss and twigs, which, from want or excess of moisture in the soil, or want of heat or lime, has remained undecomposed. The case occurs in already existing woods. To cure the evil, the wood must be thinned heavily some time before regeneration is contemplated, so as to increase the admission of sunlight and air currents and accelerate thereby decomposition. If this measure proves insufficient, part of the humus must be removed, and the rest mixed with the mineral soil.

c. Dry Mould and Bituminous Humus.

The first is formed by the decomposition of certain lichens on over-dry soil; the latter is the result of the decomposition of heather and various species of Vaccinium. Both are unsuited for young plants, and they should be removed; bituminous or acid humus may be treated with lime.

5. Fixation of Shifting Sand.

Sand of a fine grain, without a sufficient quantity of binding material, such as clay or humus, is liable to be blown about and to become moving or shifting sand, which spreads over

adjoining lands. If the supply is kept up, these shifting masses of sand form regular waves which proceed at a certain rate in the same direction as that of the prevailing wind. Shifting sands are most prevalent along sea shores, but also occur inland. In either case, but especially near the sea, they are capable of forming considerable accumulations of sand, reaching a height of 200 feet and and even more, which are called *dunes* Before such areas can be brought under wood, it is necessary to fix them, so as to allow trees to spring up and lay hold of the soil permanently.

a. Coast Dunes.

Along the sea coast, the waves constantly throw up sand, which, after drying, is carried inland by air currents, forming a series of ridges and valleys, in many cases, though not necessarily, parallel to the sea shore. These sand hills move steadily forward, being replaced behind by fresh sand thrown up by the sea. The rate of progress varies considerably according to circumstances. On the west coast of France it is said to be about 14 feet a year, but as the process has gone on for a long period of time, an enormous area comprising millions of acres has become covered with sand. The further progress of the evil has been checked only in comparatively recent times by operations which it is useful to describe shortly in this place.

The measures which must be taken are:—

(1.) Cutting off a further supply of sand from the sea.

(2.) Fixing the sand temporarily, so as to allow sowing or planting.

(3.) Growing a crop of trees and bushes, which will permanently fix the sand.

(4.) Maintaining permanently a crop of trees and shrubs.

The first of these four measures is based on the fact that, although air currents are capable of moving the sand along level and gently sloping ground, they cannot lift it above a certain height. Hence, it is necessary, at a moderate distance

(100—300 feet) from high water level, to form an artificial hill, which is high enough to arrest the forward movement of the sand, and this is done by the construction of an artificial dune, generally called the "littoral dune." For this purpose, a continuous line of paling is erected, consisting of planks about 6 feet long by 6 inches wide, 1 inch thick, and pointed

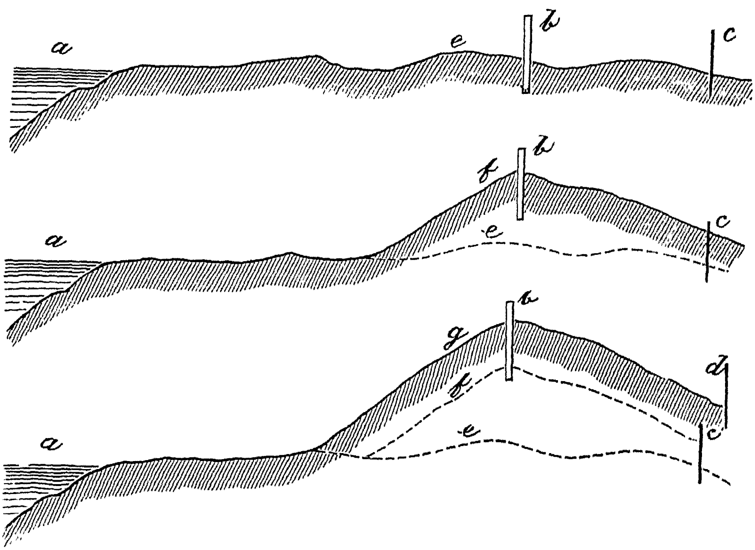

Fig. 25.

a. Sea level.
b. Paling in three successive positions.
c. First wattle fence.
d. An additional wattle fence.
e. Original surface of littoral dune.
f, *g*. Surface of littoral dune in two subsequent stages.
(The heights are exaggerated.)

at the lower end. The planks are inserted into the ground to about half their length, an inch apart, the direction of the line being parallel to the coast. Against this fence the sand is deposited, a certain portion being forced through the interstices and coming to rest in the comparatively quiet air immediately behind the paling. As soon as the accumulation of sand approaches the upper ends of the planks, they are

pulled up about 3 feet by means of levers, and this process is repeated until the artificial dune has reached such a height that no sand can be carried over the top (see Fig. 25). Simultaneously with the first erection of the paling, a wattle fence is placed at a convenient distance behind it, to prevent the sand, which has passed through the paling, from being carried inland; when the first wattle fence has been entirely covered, a fresh one is made to replace it. In this way the dune is forced to adopt a moderate slope on both sides, which is essential to its permanent maintenance. The latter is effected by growing on it certain plants which are capable of living under such conditions. Among these, the marram grass, *Psamma (Ammophila) arenaria*, takes the first place; it has the property that, as the sand rises round it, its stalk grows higher and develops numerous adventitious roots at the joints. Other plants used for the same purpose are *Elymus arenarius* and *Carex arenaria*.

The second measure, or the temporary fixation of the area covered with sand behind the littoral dune, consists in covering the area with various materials, such as the branches of coniferous trees, heather, broom, furze, sea-weed, turf, etc.; the last, when obtainable, is best. These materials (except the turf) are kept in their place either by fastening them down with pegs, or by shovelling sand upon them.

The third measure consists in stocking the temporarily fixed area with trees, shrubs, and grasses. Of trees, the Scotch pine and the cluster pine (*Pinus maritima*) are specially adapted; seed of these may be sown, or transplants put in. Of other plants *Psamma arenaria*, *Elymus arenarius*, *Carex arenaria*, broom (*Sarothamnus scoparius*), and furze (*Ulex nana*), may be mentioned. It is essential to maintain the temporary cover until it is replaced by the permanent growth.

On the west coast of France, the second and third measures are done simultaneously. There, a mixture consisting of 9 pounds of cluster pine seed, 8 pounds of broom, and 3½

pounds of *Psammia arenaria* are sown per acre, and immediately after it the ground is covered with brushwood, which is kept in its place by occasional heaps of sand. The pines, the broom, and the marram grass come up together, and it is said that the young pines grow all the better when surrounded by the two other species.

The cost of these operations is considerable, amounting sometimes to ten pounds per acre and more; the expenditure will not be found excessive, if it is remembered that fertile lands beyond the dunes may thus be protected against being covered by sand.

b. Inland Dunes.

These are treated in a manner similar to that described in the case of coast dunes, with this exception, that the construction of a forward dune, corresponding to the littoral dune on a sea shore, may not be necessary. In many cases it may suffice to arrest the forward movement of the sand on the windward side by a wattle fence, until the ground has been covered with a growth of trees, shrubs and grasses. The temporary fixation of the sand is here frequently effected by means of pieces of turf, which are laid in rows or squares, within which the sowing or planting is done (Fig. 26).

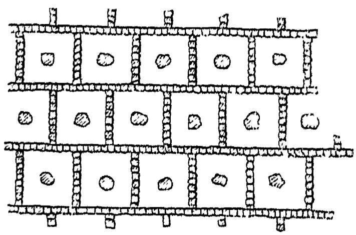

Fig. 26.

In the case of both coast and inland dunes, it is essential to keep all domestic animals out of the area, at any rate for a number of years after it has been fixed, as they disturb the sand. When the area has been stocked with trees, clear cuttings must be strictly avoided, the wood being treated under the selection system, else the work may have to be done over again.*

* For further details, see Volume IV. of this Manual.

6. Fixation of Unstable Soil on Slopes.

Owing to the action of water, soil on sloping ground may become unstable. Water filtering downwards causes a reduction in the cohesion of the different layers of the soil, followed by gradual denudation, or landslips. In water channels the banks may be undermined. The result is a reduction in the productive power of the slopes, while the level ground below may be covered with the débris brought from above; at any rate, the water channels in the low land silt up, and give rise to inundations.

The detailed consideration of this subject belongs to Forest Protection.* It will suffice here to state that the best preventive measure consists in keeping such ground permanently under forest growth, from which domestic animals should be excluded.

If a bare area exposed to denudation is to be stocked, it may be necessary to fix the soil before sowing or planting is attempted. This is done by regulating the existing water courses, terracing them, and even erecting wooden or masonry revetments. Where necessary, additional water channels must be cut to lead off all surplus water into the regular channels. Cattle of all kinds must be strictly excluded. The land itself may have to be terraced, or wattle fences erected at suitable intervals. Only after the soil has been rendered stable, can the formation of a wood be commenced.

Works of the above mentioned kinds have been executed on a large scale in the French,† Swiss and Austrian Alps, as well as in the Jura.

* See Volume IV. of this Manual.

† See "Traité pratique du Reboisement et du Gazonnement des Montagnes," by P. Demontzey. Paris: Rothschild, 13, Rue des Saints-Pères.

CHAPTER II.

ARTIFICIAL FORMATION OF WOODS.

SECTION I.—DIRECT SOWING.

By "direct sowing" is understood the formation of a wood by the sowing of seed directly on the area which it is proposed to stock. This can be done in various ways. Whatever the chosen method may be, its success depends on considerations which hold good, more or less, for all; hence, the general conditions of success must be dealt with, before a description of the different methods of sowing can be given.

A. Conditions of Success.

1. Choice of Species.

The considerations which guide the forester in the selection of the species to be grown have been given in Chapter I. In this place, attention must be drawn to the fact that under the system of direct sowing only a moderate amount of protection can be given to the seed in the ground and to the young seedlings which may spring up. Trees with delicate seeds and seedlings, or expensive seeds are, therefore, less suited to this method than hardy species which thrive easily, and especially those with large seeds.

2. Quality of Seed.

It is of paramount importance to use only good seed. The quality of the seed depends principally on its being perfectly ripe and on its weight, size, age and origin.

a. Weight and Size.

In the case of one and the same species, large heavy seeds are better than small light ones. The former generally possess a greater germinating power, and the resulting

seedlings show a greater power of resistance against external injurious influences, and a more vigorous development, which in many species is due to the greater quantity of reserve materials deposited in the seed. This superiority at the first start should not be under-estimated, because it is recognisable long after the seedling stage has been passed. In many cases, the dominating trees grow out of the seedlings which had the best start.

The actual weight of good seed varies according to locality. The following figures are given as examples; they represent averages for clean seeds without wings calculated from the best available data:—

	Number of Seeds per pound.
Sweet chestnut	100
Oak, pedunculate	130
Oak, sessile	160
Beech	2,000
Maple (sycamore)	5,000
Ash	6,500
Lime, broad-leaved	5,000
Lime, small-leaved	12,000
Hornbeam	15,000
Common elm	60,000
Common alder	250,000
Birch	800,000
Robinia	20,000
Silver fir	8,000
Austrian pine	23,000
Weymouth pine	23,000
Corsican pine	32,000
Douglas fir	40,000
Common spruce	60,000
Sitka spruce	180,000
Larch	70,000
Scotch pine	75,000

b. Age.

The germinating power of seed is greatest immediately after ripening; it can be maintained for a shorter or longer period according to species and treatment. It follows that the sooner seed is sown after ripening the better. This becomes absolutely necessary in the case of elm seed, as it only keeps for a very short time. The seeds of birch, alder, silver fir, sweet chestnut, beech and oak may be kept until the following spring, but seeds of these species more than six months old should not be used. In the case of lime, hornbeam, maples, ash, larch, spruce and Scotch pine, seed up to two years old may be used; if older it should be rejected.

When seed is stored, it must be protected against moisture and heating by keeping it in an airy locality and turning it over from time to time.

c. Source.

The source, whence seed has been obtained, is of importance. Although trees of all ages can yield excellent seed, as a general rule it may be said that the best seed is derived from trees which are in the prime of life, namely healthy trees with a full crown, which have just completed their principal height growth. At the same time, soil and climate, and especially the latter, are of greater importance than the age of the trees.

The question has been raised, whether it may be advantageous to obtain from time to time seed from another locality, as is done in agriculture. This may become desirable, when the trees are affected by disease or by peculiarities which are transmitted through seed; apart from such cases, it is probably better not to change the seed. Trees live for a long space of time, and they accommodate themselves to a locality, so that home grown seed is likely to do best.

Of late years, a heated controversy has been carried on over the question of heredity, in so far as it influences the shape of the tree; more particularly, whether the tendency to grow straight or crooked is inherited through the seed. It has, for

instance, been maintained in the case of Scotch pine that seed taken from straight trees will again produce straight trees, and *vice versâ*. On the strength of this hypothesis, it is claimed that the seed should be obtained from localities where the majority of trees grow straight. Others maintain that the question of straight or crooked growth is decided by local conditions, especially the climate. As the question is still *sub judice*, it is not proposed to deal further with it in this place.

d. Testing Seeds.

The quality of seeds can be judged by their external and internal appearance. Good seeds fill up the outer coat, are of a good rich colour, possess a healthy smell, and look fresh in the interior when cut open. The percentage of good seed can, in the case of heavy seeds such as acorns, sweet chestnuts, and beech nuts, be judged by putting them into water, when those properly developed will sink, while the bad and inferior ones will float on the surface.

When accurate information is required, regular germinating tests must be applied. These consist in subjecting a certain number of seeds, usually 100, to conditions which secure quick germination, namely a steady degree of moisture, a temperature of 60—70 degrees Fahr., and free admission of air. Any arrangement which secures these conditions will do; as instances the following may be mentioned:—

The Pot test.—Fill a shallow, porous flower pot with loose earth, place the seeds on the earth, cover them with some moss, maintain an even temperature, and water periodically, or better still, place the pot inside another containing water. The seeds should be removed as they germinate, keeping an account of them day by day.

The Flannel test.—Place the seeds between two pieces of flannel, or filtering paper, maintain an even temperature, and water steadily either by a spray or by connecting the flannel with a dish of water.

Of late years, a considerable variety of germinating dishes have been invented, but it is doubtful whether any of them surpass the more primitive tests described above, especially the flannel and filtering paper tests.

The percentage of seeds fit to germinate differs much, not only according to species, but also in different samples of seed of the same species. Seed may be considered good if a carefully conducted germinating test gives the following percentage of germinable seeds:—

Spruce	75 per cent.
Austrian pine Scotch pine Corsican pine	70 ,, ,,
Hornbeam Oak Beech	65 per cent.
Sweet chestnut	60 ,, ,,
Ash Sitka spruce Maple (sycamore and Norway)	55 ,, ,,
Weymouth pine Robinia Lime Douglas fir	50 ,, ,,
Silver fir	40 ,, ,,
Larch, Tyrolese and Japanese	35 ,, ,,
Elm (common and mountain) Alder, common	30 ,, ,,
Birch	20 ,, ,,

3. Quantity of Seed.

The density of a forest crop should be sufficient, on the one hand, to give a proper shelter to the soil, and on the other, to provide for each tree that growing space which is best suited for its proper development. The first object will be

obtained by thick sowing, but in that case the development of the trees would soon be interfered with; hence, a mean must be struck; in other words, the density of the young crop should be such that a fair cover overhead will be established within 5—10 years after sowing. This consideration governs the quantity of seed to be sown per unit of area. The actual quantity depends on the quality of the seed, the nature of the soil, the mode of growth of the species, and the dangers to which the seed and the young seedlings are exposed. Of these, the quality of the seed has already been dealt with.

The Soil.—Almost any soil can nourish a full crop of seedlings, so that the chemical composition of a soil becomes of importance only after the young crop has closed up and the struggle for existence commenced. Of far greater importance, during germination and the early stage of life, are a proper degree of moisture, heat and porosity. A dry, loose, stony soil, and again a hard, cold soil requires more seed than a fresh soil of middling porosity.

The Mode of Growth.—In the case of species which are of quick growth during youth less seed is required, than for others which grow slowly at first and do not close up for some time.

External Dangers.—The seeds are liable to be eaten by animals. Amongst these, birds are most injurious. To protect small seeds against birds, they may be coated with red lead. Mice may be caught in traps or poisoned. The young seedlings are subject to injury by animals, fungi, the effects of climate such as frost, drought, excess of moisture, and they are liable to be choked by weeds. The quantity of seed to be sown is governed by the extent to which such injuries may be expected to take place in any given locality.

Although it is, therefore, impossible to give the actual quantity of seed required in any particular case, the following figures may be taken as illustrating, under average conditions,

the necessary quantities in the case of broadcast sowing, the seed being of good quality and clean :—

	Quantity of Seed in Pounds per Acre.
Oak	550
Beech	150
Hornbeam, Ash	35
Maple, Birch	30
Elm	25
Alder	15
Silver fir	40
Larch	14
Spruce	10
Scotch pine	6

In the case of partial sowing, the quantity of seed is proportionately smaller ; thus for

Sowing in strips, furrows, or trenches	about 65—70°/₀	of	broadcast sowing.
,, ,, patches	50 ,,	,,	,,
,, ,, pits or holes	25—35 ,,	,,	,,

4. Conditions of Germination.

The process of germination is as follows :—

(1.) Swelling of the seeds.

(2.) Chemical change of the nourishing substances deposited in the seed.

(3.) Development of the embryo.

The swelling of the seed is due to the absorption of water. If then a sufficient amount of heat and oxygen are available, the reserve materials are changed into soluble substances fit for the formation of new cells; growth then sets in, which causes an enlargement of the embryo followed by the bursting of the shell of the seed and the protrusion of the rootlet.

The conditions for the successful germination of forest seeds are thus:—

(1.) A constant but moderate supply of water.

(2.) A temperature not lower than 45°, but better from 55—75° Fahr.

(3.) Admission of air, whence the oxygen is derived.

The presence or absence of light is of no importance.

These conditions can easily be provided in the case of small experiments, but in operations conducted on a large scale they can only to a certain extent be secured by a suitable condition of the germinating bed, by sowing at the most suitable time of year, and by the manner of covering the seed.

a. The Germinating Bed.

A suitable condition of the germinating bed is of prime importance; it is secured by working or loosening the soil, in some instances by draining or irrigating, and in exceptional cases by manuring.

Loosening the soil secures the following advantages:—

(1.) It enables the roots to spread more readily, and to penetrate deeper into the ground, thus rendering the young plant more independent of variations of moisture in the surface soil.

(2.) It effects a mixture of the different layers of the soil, thus rendering the nourishing substances more readily available and causing greater activity in chemical changes.

(3.) It freely admits air and heat.

(4.) It exercises a favourable effect upon the degree of moisture in the soil. Rain water penetrates more readily and to a greater depth, while subsequently, during dry weather, it rises again by capillary attraction.

On the other hand, the following drawbacks must be mentioned:—

(1.) On steep slopes loosening the soil may be followed by

denudation, as rain water can more easily carry it away.

(2.) Frost lifting is more likely to occur.

(3.) It may attract injurious insects, such as the cockchafer, the larvæ of which are very destructive in gnawing the roots.

The degree of loosening, and the depth to which it may reach, depend on the original condition of the soil. Hard or wet soil requires more, naturally loose soil less or no working.

In some cases, the actual process of loosening the soil must be preceded by the removal of an obstructive surface covering, such as woody shrubs, weeds, grass, moss, ferns, heather, raw humus, etc.; in other cases this is not necessary. The loosening itself can be done in a variety of ways: by means of tools, such as the plough, harrow, rake, hoe, or spade; by allowing it to be broken up by swine; or by a temporary cultivation of field crops. Whether the one or other is preferable, depends on the method of sowing and the cost of the operation.

Too much moisture may prevent or retard germination, may obstruct aeration of the soil, or render it cold and cause the seed to rot. These inconveniences can be prevented, either by a better distribution of the water, or by draining. The latter plan should be restricted to cases where the moisture is really excessive, and where no injurious effect upon adjoining areas is likely to be produced. In forestry, it is better to drain too little than too much; in many cases, the forester will do well to be satisfied with a species which will grow in moist or wet soil, rather than endanger the proper development of valuable crops growing on adjoining lands.

Irrigation may become necessary where the soil is excessively dry. It is an expensive operation, and the outlay will be recouped only in special cases.

Manuring rarely occurs, except in nurseries, because it is too expensive compared with the increase in the returns

which it is likely to secure. However, the question has received more attention of late years.

b. Time of Sowing.

Nature sows in autumn in the case of most species growing in temperate Europe, in some cases in summer, and in others in winter or spring; hence, no absolute guide can be given as to the best time for sowing. Of the naturally sown seed, a large portion, while lying over winter, is eaten by animals, or perishes through adverse influences of the weather, so that only a small portion actually germinates in spring. In artificial sowing, the seed must be carefully husbanded; hence, sowing should be done at the most favourable season for germination, namely when the soil is sufficiently moist and when sufficient heat is available. The best time for sowing in temperate Europe is during April and May, according to the local climate.

The above rule is subject to exceptions, because some seeds will keep in good condition only for a very short period, or their preservation involves much trouble and expense. The seed of the elm ripens, on an average, at the end of May or in the early part of June, and loses its germinating power very rapidly; hence, it should be sown at once. Birch seed also should be sown as soon as it ripens, about the beginning of August. The seed of silver fir ripens in autumn, and, as it does not keep well, it should be sown at once, and not kept till spring. Many foresters prefer sowing heavy seeds, like those of oak, beech and sweet chestnut, in autumn, because they are bulky, and it is expensive to keep them in good condition over winter. At the same time, these heavy seeds are much exposed to attacks by animals during winter, and, as autumnal sowings germinate early in spring, the seedlings are exposed to late frosts; hence, sowing them in autumn may be of doubtful expediency.

In some cases, autumn sowings are indicated in localities which are not accessible until late in spring, such as high

altitudes where snow does not disappear before June. Again, alder seed is frequently sown in winter, immediately after harvesting, as it is difficult to keep until spring.

To sum up, it may be said that, in temperate Europe, spring sowing should be the rule, but that certain species and certain local conditions demand exceptional treatment.

In other parts of the world, under different climatic conditions, the best time for sowing also varies according to circumstances. In the Indian plains and low hills, the general rule is to sow at the commencement of the summer rains, because the seeds will then be assured of a sufficient supply of moisture, and the seedlings will have time to establish themselves thoroughly in the ground, before the next dry season comes round. Sowings on irrigated lands can be made at other seasons. The seed of some Indian species does not keep, and indeed the seed of Sal (*Shorea robusta*) often germinates before it falls, and must therefore be sown as soon as it ripens. In those regions of the Himalayas where snow may lie until late in the spring, both autumn and spring sowings are made, there being perhaps no decided balance in favour of the one or the other season.

c. *Covering the Seed.*

The objects of covering the seed are chiefly the following :—

(1.) To protect it against sudden changes of moisture and temperature.

(2.) To protect it against being eaten by animals, especially birds, or being carried away by wind or water.

In natural woods, large quantities of seed fall to the ground; some of it is carried by rain water through the vegetable covering down to the mineral soil, thus finding conditions favourable for germination. In artificial sowings, the necessary protection is afforded by covering it with earth to a certain depth.

The thickness of the covering is of considerable importance; if too thin, the seed is exposed to attacks by animals,

is liable to dry up or to be injured by frost; if too thick, germination is retarded, the seedlings have great difficulty in pushing through the covering, and germination may altogether fail for want of sufficient air. The actual thickness depends on the general condition of the seed bed and the species. It must be thicker in the case of loose or dry soil, and thinner in firm or wet soil.

The seed of different species requires a different covering. On the whole, large seeds, such as acorns and chestnuts, require the thickest covering; considerably less, the seeds of beech, maple, hornbeam, silver fir: less again, those of alder, ash, Scotch pine, spruce, and larch; least, those of elm and birch.

On loamy sand the best results are likely to be obtained with coverings of the following thickness:—

Oak	1·50—2	inches.
Beech	·75—1·25	„
Sycamore and silver fir .	·60—1·00	„
Scotch pine, spruce and larch .	·50	„
Common alder	·40	„
Elm	·12	„

The seed can be covered in various ways, by ploughing (in the case of acorns), harrowing, raking, light hoeing, or by scattering fine earth over it. Some small seeds, such as that of *Ficus elastica*, need not be covered at all.

d. Sprouting of the Seed.

During germination, the rootlet is first developed, and then the stem; as soon as the latter breaks through the surface of the soil, the seed is said to sprout. A few European species, such as oak, sweet chestnut and hazel, leave their cotyledons below the surface, but the majority bring them above ground.

The interval of time between the sowing and sprouting depends on the species, the age of the seed, and the conditions of germination.

Species.—Good seed sown in spring, under average con-

ditions, may be expected to sprout after a lapse of time ranging from a week up to two and even three years. The following data may be taken as illustrations:—

Poplars and willows . .	after	about	1—2	weeks.
Elm and birch . . .	,,	,,	2—3	,,
Scotch pine, black pine, Weymouth pine, and larch	,,	,,	3—4	,,
Spruce, silver fir . . .	,,	,,	3—5	,,
Oak, beech, maple, and alder .	,,	,,	4—6	,,

Ash, lime, hornbeam, and Cembran pine generally after one year, yew after one and often two and even three years.

Age of Seed.—Fresh seed always germinates quicker than old, the latter sometimes not until the second year.

The time of sprouting depends much on the conditions to which the seed is subject; a heavy covering retards germination; warm soil and sufficient moisture produce quicker sprouting than cold soil or drought.

Seeds are sometimes specially treated with the object of accelerating the sprouting. Amongst the various methods which have been recommended, the following may be mentioned: soaking in water, ranging from an hour to a week; treatment with lime water or highly diluted hydrochloric acid; steaming; soaking in liquid manure. Apart from the first mentioned, great care is required in applying the various treatments, else the seeds may be injured. In the case of large seeds, like those of teak, collecting them in a heap and keeping them continuously moist may considerably accelerate germination. Seeds, which germinate only in the second year, may be bedded in sand in a ditch or pit, and sown in the second spring.

B. Methods of Sowing.

In the course of time, a great variety of methods of sowing have been elaborated. It would be beyond the scope of this book to describe them all in detail; moreover, they can only be fully understood by studying them in the field. Hence,

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M 2

only the more important methods will here be mentioned. Sowings may be divided into :—

(1.) Broadcast sowing.

(2) Partial sowing.

1. Broadcast Sowing.

If the seed be distributed evenly over the whole area to be stocked, the method is called broadcast sowing.

a. Preparation of the Soil.

In some cases broadcast sowings are made without previous or subsequent cultivation, but they are liable to lead to disappointment, unless executed under specially favourable circumstances. The soil must be naturally free and capable of retaining moisture near the surface; the seed must germinate readily and be sown in large quantities; the locality must be free from climatic extremes, and the surface of the ground not very steep, or the seed may be washed away; the seedlings must be hardy. Such a combination of conditions is only exceptionally met with.

As a general rule, the soil requires some cultivation before the seed is sown. This can sometimes be done at once; in other cases it must be preceded by the removal of an objectionable covering.

Removal of Surface Covering.—This may consist of shrubs, weeds, reeds, or excessive layers of moss and leaf mould. It may be removed, according to circumstances, with billhooks, knives, scythes, rakes, hoes, or by hand. The refuse may be used for litter or other purposes, or it may be burned when dry, the ashes being scattered over the area. If the covering is sufficiently dry, the area may be burned over without previously collecting the material, care being taken that the fire does not spread into adjoining woods.

In the case of a short weed growth, or a moderate layer of moss or raw humus, it need not be previously removed, but may be dealt with simultaneously with the loosening of the soil.

Cultivation, or Loosening the Soil.—This can be done in a variety of ways, according to the required depth of cultivation. The tools used are principally the following:—

For superficial loosening or so-called *wounding* of the soil .	The rake, harrow, or a light hoe.
For moderately deep cultivation .	The hoe.
For deep cultivation . . .	The plough, or spade.

Superficial loosening or wounding the soil is indicated on localities which are already of a fairly loose consistency, and covered with a moderate amount of turf, moss, or leaves.

Hoe cultivation is in its place when the soil is somewhat heavier, uneven, stony, or where the roots of a previous crop of trees are still in the ground.

The use of the *plough* is restricted to fairly level areas, comparatively free from stones, stumps, or big roots. Attempts have been made to introduce ploughs of specially strong structure for the cultivation of stony soils or for breaking up soil containing roots; their application is, however, limited. By way of illustration, a plough constructed by Dr. Weber is given on page 166. It works the soil to a depth of 12 inches, and is automatically lifted over roots, stones, etc.

Spades are the best of all instruments for cultivation, but work performed with them is too expensive for ordinary forest operations; hence their use is generally restricted to nurseries, for trenching areas with an impermeable substratum, or for planting.

In the case of light and middling soils, the loosening may be done immediately before the sowing of the seed. Heavy soils, or those containing considerable quantities of raw humus, heather, broken up impermeable layers, woody weeds, etc., should be worked in autumn and remain unsown over winter, so as to be subjected for some time to the action of air, rain and frost. Such soils may require a second, more superficial, working in spring before the seed is sown.

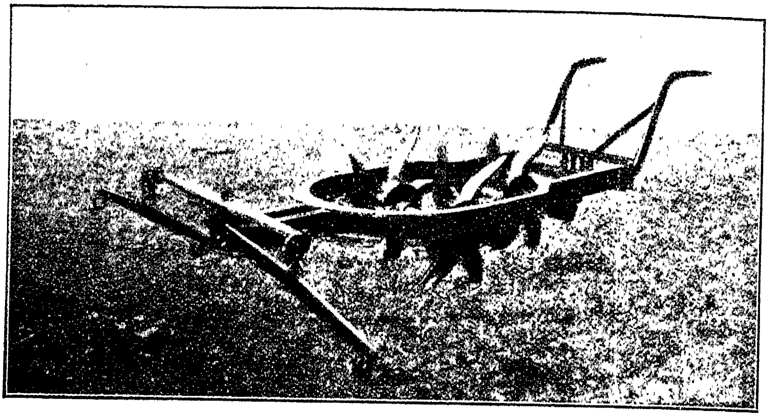


Fig. 27.—Dr. Weber's Forest Plough.

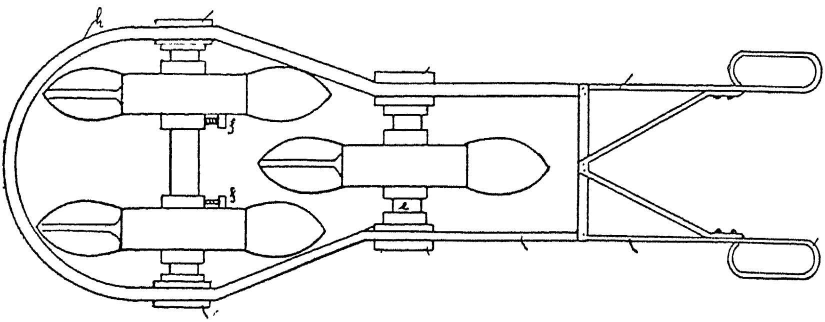


Fig. 28.—Forest Plough, seen from above.

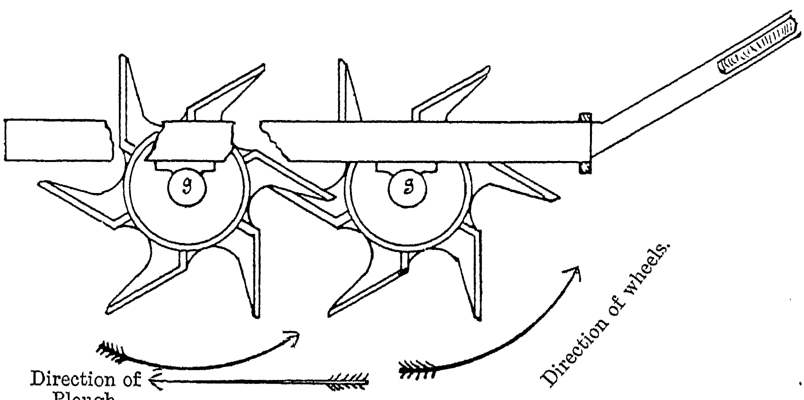


Fig. 29.—Side View of Forest Plough.

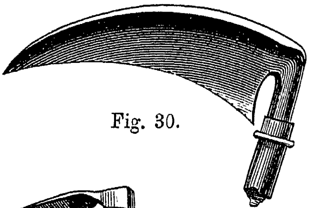


Fig. 30.

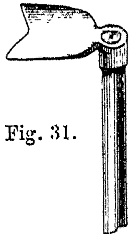


Fig. 31.

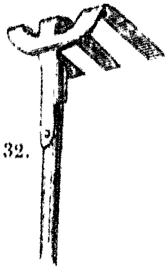


Fig. 32.

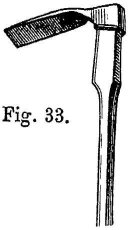


Fig. 33.

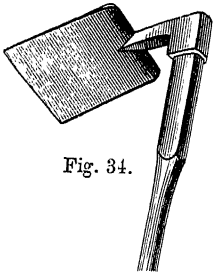


Fig. 34.

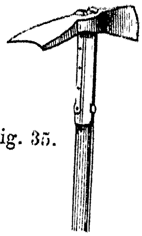


Fig. 35.

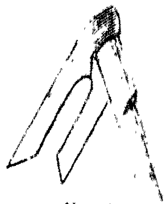


Fig. 36.

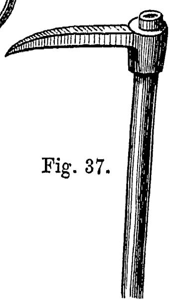


Fig. 37.

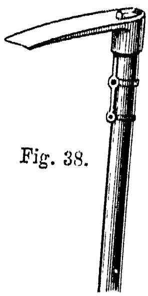


Fig. 38.

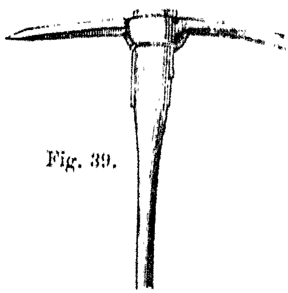


Fig. 39.

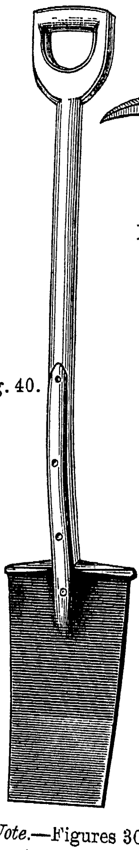


Fig. 40.

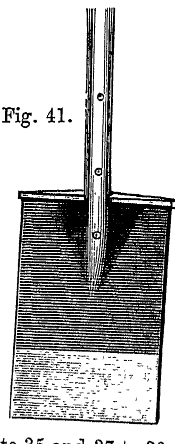


Fig. 41.

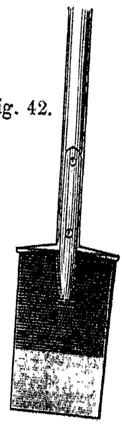


Fig. 42.

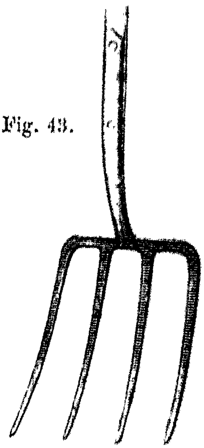


Fig. 43.

Note.—Figures 30 to 35 and 37 to 39 are taken from Heyer's Waldbau, Figure 36 from Gayer's Waldbau, and Figures 40 to 43 from Messrs. Thos. Black & Sons' catalogue (Berwick-on-Tweed).

Many and various are the forms of the several tools which have from time to time been recommended for use in the preparation of the soil. Of these, a considerable number are of doubtful utility. As a general rule, the ordinary labourer gets through more and better work by using the tools with which he is acquainted, than by substituting even an improved form of tool, the use of which he has first to learn. Moreover, he will take greater care of his own tools than of those provided for him.

Under these circumstances, the introduction of novel tools can only be recommended when their use really secures a considerable saving of labour.

Some of the better forms of the principal tools here in question are represented on page 167. The following few remarks will explain their use:—

Fig. 30 represents a scythe with a short strong blade, used for cutting heather, broom, etc.

„ 31, a hoe used for the removal of ordinary weeds, grass, etc.

„ 32, a three-pronged hoe, used for wounding the soil.

„ 33, a narrow light hoe, used for superficial hoeing in light soils.

„ 34, a broad hoe, used for clod hoeing.

„ 35, a light hoe with a hatchet on the reverse (or a miniature mattock), used for hoeing in soil which contains roots from a former crop.

„ 36, a two-pronged hoe, used for light hoeing or wounding the soil.

„ 37, a simple pick, used in working stony or gravelly soil.

„ 38, a strong hoe, used on soils with roots, or on stony ground.

„ 39, a pickaxe, being a combination of figs. 37 and 38.

„ 40, an Irish spade.

„ 41, a Scotch planting spade.

„ 42, a light planting spade.

„ 43, a four-pronged digging fork.

b. Sowing.

Seed may be sown by hand or by machines. The latter can be used only on fairly level ground, with a loose soil free from stones and roots; they frequently cover the seed at the same time. In the majority of cases, the sowing will have to be done by hand. The essential point is to distribute the seed as evenly as possible; hence, it is desirable to divide large areas into smaller sections, and to allot a proportionate quantity of seed to each. The sowing of small seeds is done as in the case of ordinary grain sowing. A good plan, in the case of level or moderately sloping ground, is to sow cross-wise; that is to say, to divide the seed into two parts, to sow one half in one direction, and the other half at right angles over it. This plan can, however, not be adopted on steep ground. Light seed should not be sown during windy weather, as it would be unevenly distributed.

Where seeds of two species are to be sown, they should be thoroughly mixed before sowing; if they differ in size or weight, it is best to sow them separately, or one cross-wise over the other.

Heavy seed may be placed in plough furrows, or singly brought into the ground.

c. Covering the Seed.

The method of covering the seed depends on the mode of working the soil and the size of the seed. In the case of shallow working and light seeds, the harrow and rake are the most useful tools to use; in some cases it may suffice to drive a flock of sheep over the area, which will press the seed into the soil by trampling on it. Where heavy seeds are to be covered on level ground, the operation may be done by light ploughing, or with the rake or hoe.

d. General Remarks.

Broadcast sowing is generally expensive, owing to the cultivation of the soil, and because it requires a large quantity

of seed; hence, it should be restricted to localities which require little or no cultivation, or where a raw soil and a strong growth of shrubs and weeds necessitate under any circumstances a thorough cultivation, before success can be expected. In some cases, the operation may be combined with the raising of one or more field crops, thus recouping the cost of cultivation.

2. Partial Sowing.

With a view to reducing the cost of cultivation and the quantity of seed, the sowing may be restricted to a portion of the area to be stocked. The method may become necessary in the case of localities which contain rocks, stumps of trees, or which are too wet for full working and sowing. In either case, it is desirable that the portions to be sown should be distributed as evenly as possible over the whole area; they can be arranged in a variety of ways, of which the following may be mentioned:—

a. Sowing in strips and furrows.
b. ,, ,, patches.
c. ,, ,, holes.
d. ,, ,, trenches, or pits.
e. ,, on ridges, or mounds.
f. Combinations of two or more methods.

a. Sowing in Strips or Furrows.

The seed bed generally consists of strips which alternate with unsown strips or bands (Fig. 44). Where rocks or other obstacles are met with, the strips will be interrupted; the same may occur on sloping or uneven ground. The strips should, as far as practicable, run parallel to each other. On sloping ground, they should follow the contour lines of the locality and be level, or nearly so, to prevent denudation. On very steep slopes, the seed beds may form terraces.

The width of the sown strips depends principally on the degree to which the unsown strips are likely to be overrun by

weeds, brambles, etc., and on the rate of height growth of the species during early youth: the greater the former and the slower the latter, the broader should be the sown strips. Generally, the width would range between 18 inches and 3 feet.

The distance between the strips depends on similar considerations. In addition, the desired density of the wood has to be considered. The distance would ordinarily range between 3 and 6 feet.

The cultivation of the soil is generally done with the hoe

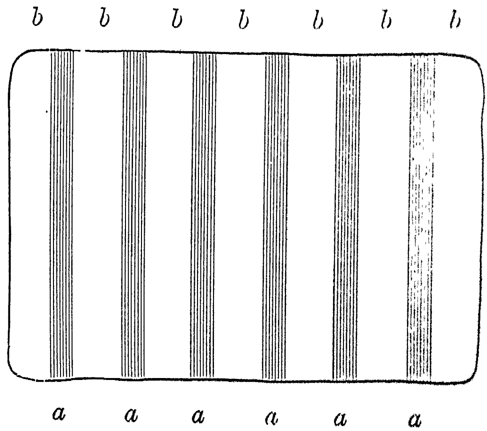


Fig. 44.

a, a. Sown strips. *b, b.* Unsown areas.

or plough; the sowing is best done by hand, a method which various machines have not yet succeeded in superseding. The seed should be covered up with rakes or harrows, and in the case of heavy seeds sometimes with the plough.

Apart from a reduction of expenditure, strip sowing has other advantages over broadcast sowing; the soil can, without incurring an excessive expenditure, be more carefully prepared and the seedlings more effectually protected.

When each strip consists of one or perhaps two furrows drawn with a plough, the method is called *sowing in furrows*; it is specially employed in the case of heavy seeds, which are sown in the furrow and covered, either by drawing a second

furrow, or with the rake or hoe. It admits of a further reduction of expenditure as compared with ordinary strips.

b. Sowing in Patches.

The seed beds consist of round, oblong, square or rectangular patches of limited extent, scattered as evenly as practicable over the area. The extent of the patches varies according to circumstances; they may be of any size, but are mostly from 1 to 3 feet square, or they assume the shape of interrupted strips, which are from 1 to 2 feet broad and perhaps from 3 to 10 feet long. The distance between the patches depends on the same considerations as in the case of strip sowing.

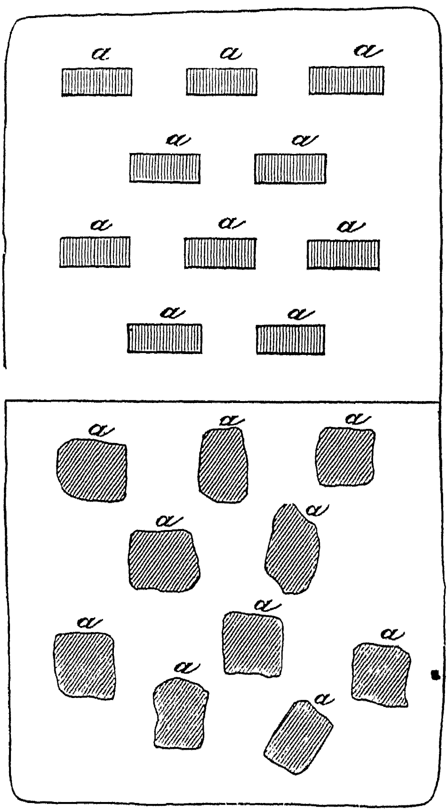


Fig. 45.
a, *a*. Sown patches.

The method is cheaper than the regular strip sowing; it enables the forester, on uneven or rocky soil, to select the most suitable spots for the seed beds, a matter of greater moment than a mathematically even distribution of the patches.

The working of the soil is best done with the hoe; on stony soil, hoes with narrow and very strong blades are used, or even the pick may be required. The seed

is covered with the rake or by hand, or by scattering earth over it.

The method is well adapted for rocky soils, and localities which still contain the stumps and roots of a former crop of trees. It is less to be recommended for wet soil, as the water is likely to collect on the sown patches; this would, on the other hand, be an advantage in localities with a scanty rainfall. Where a strong growth of tall weeds is apprehended, the patches must be of sufficient size to prevent the plants from being overgrown.

c. Sowing in Holes, and Dibbling.

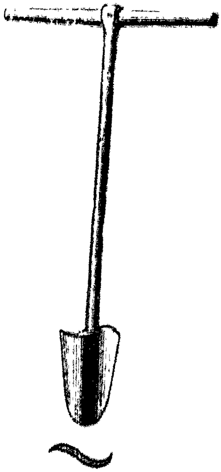


Fig. 46.

Sowing in holes means sowing in patches of such limited extent that only a few seeds are sown in each. The soil may be worked with an ordinary hoe of small size, with a spade, or with specially constructed modifications of the latter, such as the *spiral spade* (Fig. 46). On stony soil, the pick may be used. The spiral spade is forced into the ground and then turned round, so that a seed hole filled with loose soil is produced. The seed is either pressed into the soil to the required depth, or placed on the surface and covered by hand with a sufficient quantity of fine earth, which is gently pressed down.

If the seed bed is still smaller and consists simply of a narrow hole sufficient to take one or two seeds, which are sown without any preparation of the soil, the method is called "*dibbling*." The minute holes are made with a peg, dibbling mallet, dibbling spade, or any other suitable tool. The instrument is inserted into the ground to the required depth, withdrawn, the seed placed in the opening thus produced, and the latter closed again either by one or more blows with the instrument, or by pressure with the foot. In

some cases, the operation may be done without any instrument at all, by removing a small quantity of the surface soil with the foot, inserting the seed, replacing the previously removed earth, and pressing it down.

The method is only admissible on soils which are not subject to a heavy growth of weeds, which would probably smother the young seedlings; moderately sized stones or gravel do not interfere with the adoption of the method.

d. Sowing in Trenches, and Pits.

In the methods so far described, the seed bed is situated on the same level as the surrounding ground. In the case of

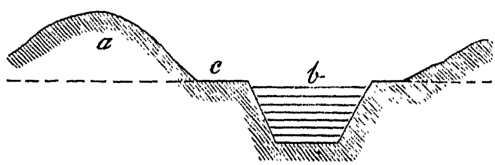


Fig. 47.

a. Soil taken out of the trench. *b.* Trench filled with water. *c.* Seed bed.

trench and pit sowing, it is placed below the ordinary surface of the ground, at the bottom of a trench or pit, in which water may collect. The general arrangement of the trenches or pits is the same as in the case of strips or patches respectively. Trenches must be level, to prevent their becoming water channels. For the same reason, they should be interrupted here and there.

The width of the trenches will, as a rule, not exceed two feet at the bottom; the depth depends on the requisite amount of water. The distance between the ditches or pits depends on the same considerations as in strip and patch sowings.

The trenches may be made with the spade, hoe, or pick, or partly with the plough and the rest with those tools. The surface soil is kept apart and placed at the bottom of the

trench to serve as a seed bed, or better still, it is at once placed into the previously made trench.

The seed is sown by hand and covered either by hand or with a rake. Where the trenches can be filled artificially with water, or irrigated, the seed is frequently sown on the upper edge of the ditch (Fig. 47), so that it receives sufficient moisture by percolation, without being destroyed by an excess of water. Where irrigation water is not available, and the rainfall variable, seed may be sown both at the bottom of the ditch and along one of the upper edges. In the case of a scanty rainfall, the former will succeed, and in case of a wet year, the latter.

The method is indicated in dry hot localities, and where irrigation is practicable. As it is expensive, it should be adopted only in cases where a cheaper method is not likely to yield satisfactory results. The pit method is cheaper than trench sowing, but it frequently yields less favourable results, and is not applicable where irrigation is contemplated.

e. Sowing on Ridges and Mounds.

This method is the reverse of the one described under *d.* It is advisable in the case of wet or heavy soil, the object being to raise the seed bed above the water level, and to expose the soil to a more complete action of the air. Mounds are interrupted ridges, just as patches are interrupted strips. The ridges or mounds are formed, either by drawing together the surface soil, or better by excavations. In the case of ridges, the ditches run along either one or both sides; in the case of mounds, the earth may be taken from an excavation on one side, or from a trench surrounding the mound.

Where a moderate elevation suffices, parallel ditches may be dug, and the excavated earth spread evenly over the intermediate spaces, thus forming elevated platforms on which the seed is sown. See Fig. 24 on page 143.

The seed should be sown densely and not too early in spring,

so as to allow a portion of the moisture to evaporate before sowing. The tools used are the same as for trench or pit sowings.

The method is expensive and only indicated in exceptionally unfavourable localities.

f. Combinations.

It happens not unfrequently that two or more of the different methods are combined in the same locality. Such combinations are indicated when the character of the locality changes from place to place; if, for instance, dry spots alternate with swampy ground, the former may be sown on the natural level or in ditches, while the latter necessitates sowing on ridges. Where free soil alternates with stony or rocky parts, the former may be sown in strips, and the latter in patches or holes, etc.

SECTION II.—PLANTING.

By the term *planting* is understood in silviculture the method of forming a wood by means of plants which have been raised elsewhere. The success of the operation depends principally on the manner in which the plants are raised, and on the method of planting. The subject may be divided into the following four sub-sections:—

A. Conditions of success.
B. The raising of plants.
C. The methods of planting.
D. Planting of slips, layers, and suckers.

A. The Conditions of Success.

Under this heading, the following matters demand attention:—

1. Choice of species.
2. Different kinds of plants
3. Quality of plants.

4. Age and size of plants.
5. Season for planting.
6. Density of planting.
7. Distribution of plants over the area.
8. Number of plants per unit of area.
9. Lifting plants.
10. Pruning.
11. Protection in transit.
12. Preparation of the soil.

1. Choice of Species.

Reference is invited to what has been said in chapter I., section I., p. 122. In addition, it remains to be mentioned that planting is admissible in the case of all species, and that it is specially adapted for those which are tender during early youth, and which cannot receive sufficient attention and protection in direct sowings on a large scale; also to species the seed of which is expensive, or exposed to dangers from animals.

2. Different Kinds of Plants.

The plants used in silviculture are of many kinds, according to external form, origin, age, etc. No general classification is possible, since the various groups overlap each other. For practical purposes the following divisions will prove useful :—

A distinction must, in the first place, be made between plants which have sprung directly from seed, and those which formed part of an already existing individual; hence the division into :—

(1.) Seedling plants.

(2.) Suckers, layers, or cuttings.

All woody plants can be successfully raised from seed, but only certain species from suckers, layers, or cuttings.

Rooted plants are distinguished from plants *without roots.* Seedlings, suckers, root cuttings and layers, are rooted;

cuttings taken from the stem or branches are without roots at starting, but they may become rooted by placing them in a nursery before putting them out in the forest.

Complete or incomplete plants; the former have their roots, stem and branches entire, while in the case of the latter parts of the plants may have been pruned away.

Seedlings or transplants.—The former are plants which are transferred direct from the seed bed to the forest; the latter those which were previously pricked out, once or several times, in the nursery.

Plants with balls, or lumps of earth in which the roots are embedded, or *plants without balls.*

Plants may be classified, according to *size*, as small, middle sized, and large plants, but the limits of each class differ according to the kind of plant, as well as to locality and custom.

3. Quality of Plants.

The success of planting operations is governed by the quality of the plants which are used, just as the success of direct sowings depends on the quality of the seed. Hence, only healthy, vigorous plants should be used, which are likely to bear well the interruption of growth involved in the transfer from one locality to another, under circumstances admitting only of a limited amount of attention being paid to each plant.

The vigour, or growing power, of a plant is indicated by a normal shape and a healthy appearance. The development of each part must be in due proportion to the rest; the plant should be neither tall and thin, nor too short and stout; nor should the stem be crooked, especially in the case of coniferous plants; the root system should be ample, with a fully developed system of rootlets; the crown should have a healthy green appearance, and possess numerous well developed buds. These are the general characteristics of good healthy plants. At the same time, they are subject to some modifications as

regards species, age, and the locality which it is proposed to plant. More especially, some caution is necessary in transferring plants from a rich to a poor soil; from a cool northern aspect to a hot southern one; from a low to a high situation; from a sheltered to an open spot, etc.; in other words, what is a good plant for one locality, may be only an indifferent one for a locality of a different character.

A further consideration is the shape of the root system. Plants with naturally extensive root systems either cost much to plant out, or the roots must be crowded together in an unnatural position, or they may have to be pruned, an operation which is likely to lead to disease; from this point of view, a compact root system may be considered as an essential point in a good plant, though it may not be altogether in proportion to the stem and crown.

4. Age and Size of Plants.

Plants aged from a few weeks up to ten and more years may be planted out; in fact, the age is only limited by the size and weight of the trees, and the mechanical appliances available for the transfer. In silviculture, only young plants under ten years of age need be considered. It may be said, as a general rule, that young plants are best, because the operation of planting is cheaper, the plants survive more easily the interruption of growth involved in the change, and they adapt themselves more readily to new conditions. The best age for planting out depends on the species and locality. Quick growing species can be planted out earlier than slow growing ones. Some tropical species grow so quickly that the most suitable age for transplanting may be only a few weeks. In the temperate climate of Europe, yearlings, with the exception of Scotch pine and oak, are only exceptionally planted out, as they are still too soft and have incomplete root systems. In the great majority of cases, plants from two to four years old are used, while older plants are indicated only in the case of a few species, or

where trees of some height are required, as in pastures, in frost localities, for filling up blanks in already formed plantations, to become the overwood in coppice with standards, to enable one species to hold its own against another of quicker growth, for avenues, etc.

5. Season for Planting.

The planting out is, after all, a violent operation, and is generally accompanied by more or less injury to the root system, with a temporary interruption of the growth. These disadvantages can, by special care, be reduced to a minimum, so that they affect the further development of the plant only to a limited extent. As long as the root system is completely embedded in a ball of earth, transplanting can be done at any time of the year, provided the soil is in a fit condition (neither frozen, nor too wet or dry). Again, plants, the roots of which are not embedded in a ball of earth, can similarly be transplanted with success, provided the operation is performed with care; but as this involves extra expense, it is difficult to ensure success in the case of large operations; hence, for silvicultural planting, the most favourable season should always be chosen.

The most favourable season differs according to species and the character of the locality. In temperate Europe, summer should be avoided, because at that time the plant is in full assimilating activity and most sensitive to a change of conditions, especially to drought. There remains then the period from autumn to spring. Planting may be done at any time throughout that period, provided the weather be sufficiently favourable; at the same time, mid-winter is generally the least favourable part of this period, as frost may be expected, so that practically the choice lies between autumn and spring. Each of these two seasons has its advantages and drawbacks, and the question, whether the one or other is more favourable, has been much debated.

In the case of autumn planting, any rootlets, which have been injured during the operation, may have been replaced by the ensuing spring, and the loosened earth settled down again during winter. On the other hand, the plants are likely to suffer from severe frost in their new home, or they may be lifted by alternate frost and thaw, or loosened by the action of wind. Autumn planting is preferable in the case of localities which are not accessible until late in spring, or of species which start early in spring.

Spring planting has the advantages that the period of severe frost is past, and that vegetation begins shortly after planting. On the whole, it is preferable to autumn planting in the case of most conifers, provided the work can be completed before vegetation begins. In many cases, especially when the operations are conducted on a large scale, both spring and autumn planting have to be done.

Over the greater part of India, the most favourable season of the year is the commencement of the summer rains; the plants receive sufficient moisture, and they have the whole growing season before them to settle down in their new home, and to get strong before the next dry season comes round. Land which can be irrigated may be planted at any season, provided the soil is not frozen.

6. Density of Planting.

The general principles which govern the density of direct sowing apply also here; that is to say, the cover overhead should be established within a period of from 5 to 10 years. As plants come on more regularly than seedlings grown on the spot, a smaller number per acre suffices than that required in the case of sowing. For the rest, the planting distance depends on :—

(a.) The locality, in so far as it influences the percentage of failures and the vigour of the plants.

(b.) The species, especially its degree of hardiness and

rate of height growth in early youth. Quick growing species can be planted farther apart than slow growing species. Oak and Scotch pine must be planted dense, on account of their tendency to branch.

(c.) The age and size of the plants; young and small plants must be planted closer than old and large ones.

(d.) The objects of the planting, whether timber or firewood is to be produced; whether pieces of large diameter or long boles are the objects of management; whether the wood is to serve as a protection against landslips, erosion, avalanches, hot or cold winds, etc.

(e.) The state of the market; where small produce is saleable at remunerative rates, dense planting is indicated; under the opposite conditions wider planting is more profitable.

(f.) The extent to which the growth of weeds threatens to outgrow the plants; the greater that danger, the closer should be the planting.

7. Distribution of Plants over the Area.

The distribution of the plants over the area to be stocked can be either irregular or regular. The former is done by eye measure, that is to say, after the average distance between the plants has been fixed, the planting spots are selected by eye. This system requires practice.

Regular distribution is done according to geometrical figures, the more usual of which are the following:—

(1.) The equilateral triangle, where the planting spots are at the three corners of the triangle (Fig. 48).

(2.) The square, four plants being placed at the four corners of the square (Fig. 49).

(3.) Equidistant lines or rows, in which case the plants stand at shorter intervals in the lines than the distance between the lines; the plants may be said to occupy the corners of rectangles (Fig. 50).

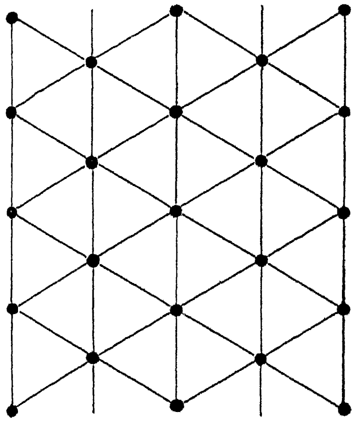


Fig. 48.

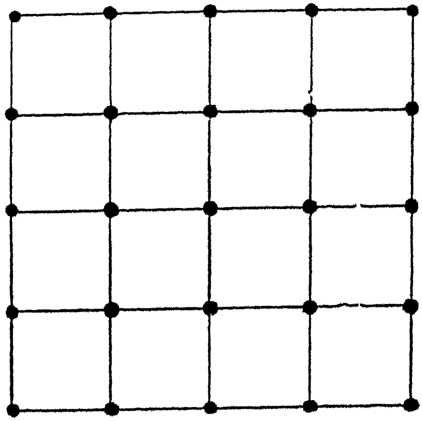


Fig. 49.

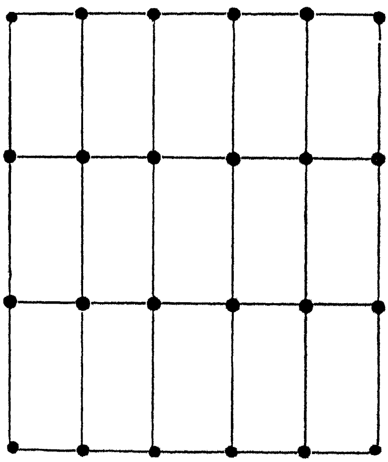


Fig. 50.

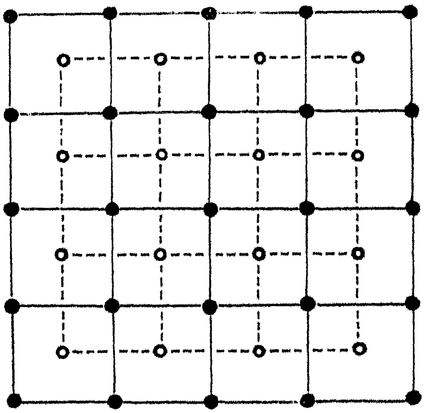


Fig. 51.

(4.) The quincunx form, a modification of the square form, as will be seen on reference to Fig. 51.

A regular distribution of the plants has the following advantages over an irregular one:—

(i.) An equal growing space is allotted to each plant.

(ii.) The plants are subsequently easier to find and to protect against being overgrown; failures are easier ascertained.

(iii.) The area between the plants can be more fully utilised; grass cutting can be allowed at an earlier stage; field crops may be grown between the lines; cattle grazing, where unavoidable, causes less damage, especially if the plants are arranged in lines.

(iv.) In mixed woods, the several species can be more evenly mixed, and it is easier to maintain the desired mixture.

(v.) Early thinnings are considerably facilitated.

(vi.) The woods can be more easily protected against damage, especially by injurious insects.

(vii.) It is claimed that regular plantings are cheaper to execute, because the work of distributing and putting in the plants proceeds in a more systematic manner. Whether this advantage is realised or not, depends on the skill of the labourers and the supervision exercised over the operations.

Against these advantages it must be mentioned that air currents have more easy access to regular plantations, may sweep away the fallen leaves or heap them together, and dry up the soil more rapidly. This disadvantage can be met by planting shelter belts of trees with branches down to the ground against the prevailing wind, or, to some extent, by arranging the planting lines at right angles to the prevailing wind direction. It is also claimed that irregular planting is preferable from an æsthetic point of view.

A completely regular distribution is not practicable, where the nature of the soil changes rapidly; for instance, where wet swampy spots alternate with dry parts, or where rocks are scattered over the area; nor is it necessary on small blanks scattered over already existing woods.

The comparative merits of the three principal forms of regular distribution have been much discussed. The triangular form allots to each plant the most regular growing space, since every plant is equi-distant from its neighbours; this favours an even development of the trees. It admits of a

greater number of plants per acre, and produces the greatest quantity of material; the saplings also clear themselves more readily of their lower branches. On the other hand, it is more troublesome to lay out and more expensive than the other forms.

Line planting has the disadvantage that the cover overhead is somewhat later established, that the saplings develop stronger branches on two sides than in the direction of the lines, which may be accompanied by an eccentric shape of the stem. On the other hand, it admits of the most complete utilisation of the ground between the lines, and facilitates thinnings and the removal of the material; the plants are also easier to find.

On the whole, these advantages and disadvantages are not of much importance, because after the early thinnings the three forms stand practically on the same footing. Many foresters prefer line planting to the two other forms, because it is easiest to carry out, and perhaps the cheapest. Others prefer the square form, while the triangular form is perhaps less frequently chosen.

The marking of the planting spots is done with two lines (or chains), the so-called *directing line* and the *planting line.* The latter is divided according to the planting distance, each division point being marked in a suitable way, either by a knot, or by drawing a coloured tape through it. On the directing line, the distance between successive rows is marked in a similar manner. In the case of square planting, the marking is the same on both lines, but different in triangle and line planting. In the latter, each division of the directing line is equal to the distance between the rows; in triangle planting equal to the planting distance multiplied by ·866.

The lines are of a suitable length, with a pin (or peg) at each end; they should be made of hemp and well tarred, to protect them against moisture. On wet soil, a wire is preferable to a line, as the latter is liable to alter its length.

When a large area is to be planted, it is desirable to sub-

divide it, in the first place, into squares or rectangles, the sides of which correspond with the lengths of the planting and directing lines (Fig. 52). After the corners of the squares or rectangles have been fixed, each plot is treated separately; the directing line is stretched along two opposite sides of it (say *a d* and *b c*), and the directing spots marked either by the insertion of small pegs or by small holes, or two directing lines may be used and left on opposite sides, until the square, or rectangle, has been planted; then the planting line is first

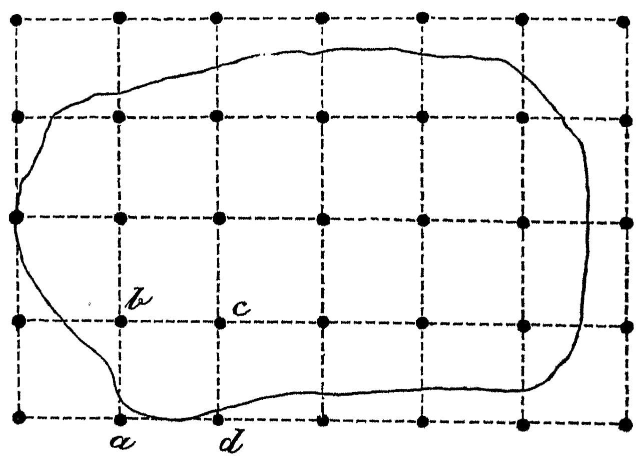


Fig. 52.

stretched along *a b*, and successively parallel to it until *d c* is reached, planting being done as indicated by the marks on the planting line.

It remains to note that in the case of triangle planting the planting line must be doubly divided, as the plants in every two adjoining rows are shifted by half the planting distance; or the planting line must be drawn back by half the planting distance in every alternate row.

The following semi-regular system of planting is much followed in Great Britain:—The planters are arranged in line at stated intervals along one edge of the area (Fig. 53, *a b*). Each puts in a plant where he stands. The most

reliable planter is placed on one flank at *a*, and he now advances a space equal to the fixed planting distance in the direction of a previously erected mark (flag), puts in a second

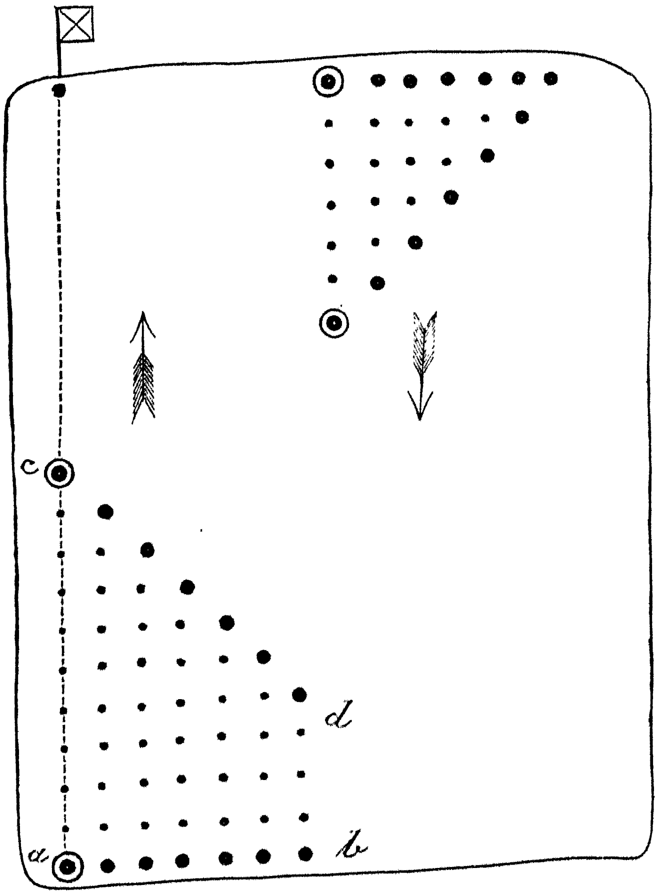


Fig. 53.

a, *b*. Original position of planters. *c*, *d*. Position when the whole column is in motion. ⊙ Flanking man, who gives the direction.

plant, advances again the planting distance, puts in a third plant, and so on, until he reaches the opposite edge of the area. As soon as the flanking man has advanced twice the planting distance, the next planter advances one

planting distance, keeping at the original distance from the first man's line, and puts in a plant. When the flanking man proceeds to his fourth planting spot, his neighbour proceeds to his third, while the third man advances; and so on, until the whole column is in motion, forming a slanting line (*c d*), each man taking his direction from his neighbour, who is always one planting distance ahead of him. When the last man has reached the opposite end of the area, the whole column wheels round and works back again, the flanking man taking his direction from the last row of plants.

The method is exceedingly simple, and yields a degree of regularity sufficient for most purposes, provided the men are well trained for the work.

8. Number of Plants.

In the case of irregular planting, the number of plants required per acre can be roughly ascertained by dividing with the square of the average planting distance, given in feet, into 43560, the number of square feet in an acre.

For regular plantations the following calculations apply:—

Line planting.

Length of area	=	L
Breadth ,, ...	=	B
Distance between the rows . . .	=	d
,, ,, plants in the rows .	=	d';

$$\text{then the number of rows} = \frac{L}{d} + 1,$$

$$\text{and the number of plants in each row} = \frac{B}{d'} + 1,$$

hence the total number of plants:—

$$N = \left(\frac{L}{d} + 1\right) \times \left(\frac{B}{d'} + 1\right) = \frac{L \times B}{d \times d'} + \frac{L}{d} + \frac{B}{d'} + 1.$$

Square planting.—Here $d = d'$ and

$$N = \frac{L \times B}{d^2} + \frac{L + B}{d} + 1.$$

Triangle planting.—Here the distance between the rows is represented by the height of the equilateral triangle, which is equal to $d \times \sin 60^\circ = d \times \cdot 866$; hence, number of rows $= \frac{L}{d \times \cdot 866} + 1$, and number of plants in each row, either alternately $= \frac{B}{d} + 1$ and $\frac{B}{d}$; or always $\frac{B}{d}$ according as to whether $\frac{B}{d}$ is a whole number, or $\frac{1}{2}$ more.

In the one case

$$N = \tfrac{1}{2}\left(\frac{B}{d} + 1\right)\left(\frac{L}{d \times \cdot 866} + 1\right) + \tfrac{1}{2}\frac{B}{d}\left(\frac{L}{d \times \cdot 866} + 1\right)$$

$$N = \frac{L \times B}{d^2 \times \cdot 866} + \frac{B}{d} + \frac{L}{2d \times \cdot 866} + \tfrac{1}{2}.$$

In the other case

$$N' = \frac{B}{d}\left(\frac{L}{d \times \cdot 866} + 1\right)$$

$$N' = \frac{L \times B}{d^2 \times \cdot 866} + \frac{B}{d}.$$

The first term in this and the two previous formulas represents the bulk of the plants. By neglecting the comparatively small number represented by the other terms, the following short approximately correct methods of calculation are obtained for each acre of plantation:—

Square planting—

$$N = \frac{43560}{\text{Square of planting distance.}}$$

Triangle planting—

$$N = \frac{43560}{\text{Square of side of triangle}} \times 1 \cdot 155.$$

Line planting—

$$N = \frac{43560}{\text{Distance between lines} \times \text{distance in lines.}}$$

Accordingly, the following numbers of plants are required per acre in the case of square planting :—

	Calculated by the Accurate Formula.	Calculated by the Approximate Formula.
Distance 2 feet × 2 feet =	10,994	10,890
,, 3 feet × 3 feet =	4,887	4,840
,, 4 feet × 4 feet =	2,749	2,722
,, 5 feet × 5 feet =	1,760	1,742
,, 6 feet × 6 feet =	1,223	1,210

9. Lifting Plants.

Plants must be lifted in the nursery with the least possible damage, especially to the root system, and least of all to the fine rootlets through which the nourishing substances are assimilated. These fine rootlets are generally imbedded in small lumps of earth, which should not be shaken off. In the case of yearlings, the rootlets are found on the taproot or its branches; on older plants they are principally found on the side roots.

The least interference with the roots occurs, if the plants are lifted with a ball of earth in which the root system is imbedded; this method is specially recommended for very young or tender plants. In the case of older plants, lifting with balls and transport become very expensive, so that, whenever admissible, they are lifted without balls of earth.

a. Lifting Plant with Balls of Earth.

The operation is performed with a variety of instruments, such as the circular spade, the hoe, the conic spade and the ordinary spade, according to the size of the desired ball.

Young plants may be lifted with the circular spade (Fig. 54), provided the species does not develop a long taproot at an early age. This instrument, which was invented by Carl

Heyer about 90 years ago, consists of an iron inverted truncated cone, which has in front an opening sufficient to admit two fingers, and behind, just above its upper edge, a small horizontal plate up to which the spade should be inserted. One of the edges of the front opening is sharp, the other blunt. The diameter at the lower end ranges from 2 to 5 inches, according to the desired size of the ball; the diameter at the upper end is from $\frac{1}{8}$ to $\frac{1}{5}$ larger, thus producing the shape of an inverted truncated cone with a circular cross section. The handle and the cross bar or crutch at the top are best made of wood and not of iron, because the tool is lighter and the crutch not so cold. The latter is firmly attached to the handle by means of three iron bands, as seen in the illustration; these are firmly fastened to the handle. The best length of the crutch is about 20 inches, and its thickness such as just to fill the hand of the labourer. The length of the handle depends on the height of the labourer, but it should not be so long as to prevent the man from using the weight of his body in driving the spade into the ground.

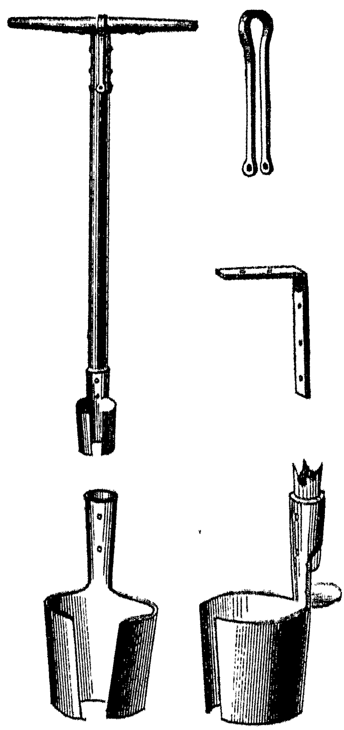


Fig. 54.

In using the spade, the stem of the plant which is to be lifted is passed through the front opening until it occupies the centre of the spade; then the latter is pressed down vertically, until the plate at the back touches the surface of the soil; it is then turned round by means of the crutch from 180 to 360 degrees, and lifted with ball and plant out of the ground;

holding it then with the left hand, the ball and plant are pushed out towards the handle with the middle finger of the right hand, which glides along the blunt edge of the front opening; if necessary, especially when using a larger sized spade, two fingers are used.

The circular spade is used of various dimensions, with a minimum diameter of 2 inches at the small end. Spades of more than 5 inches diameter cannot be recommended, as the balls are either not severed at the base or, even if severed, do not come out with the spade, but remain *in situ*. Even small spades demand a fairly binding soil, or else they will not work satisfactorily. The height of the spade is usually about equal to the diameter. The ball is cylindrical, the object of the conical shape of the spade being to facilitate its removal. The instrument works expeditiously and cheaply; extensive areas have been planted with it. The seedlings are obtained by broadcast sowing. The instrument is also very useful in lifting plants and planting them into blanks on areas which had been previously sown, and where the plants have come up irregularly.

The *hoe* is also used for lifting young plants with balls; it is inserted from one side so as to get underneath the plant, which is then lifted up. The operation requires skill, and even then the method is of doubtful utility, as the balls are likely to fall to pieces. The ordinary *planting spade* (Fig. 41, p. 167) and the *Irish spade* (Fig. 40, p. 167) are used for the lifting of larger plants. The operation necessitates four insertions, and it produces an inverted pyramidal ball. The *semi-circular spade* (Fig. 55) is also used for lifting larger plants; it necessitates only two or three insertions. The *semi-conical spade* (Fig. 56) is so constructed that it requires only one insertion, after which it is turned round its axis, thus separating a ball of earth of an inverted conical shape. The instrument can be recommended.

On stony soil a heavy, specially strong spade (Fig. 57) is sometimes used.

b. Lifting Plants without Balls of Earth.

This is done with the spade or the two, three or four-pronged fork (Fig. 43, p. 167), which is inserted from one side and bent down backward, so that the plant is gently lifted up and gradually separated from the soil.

A better method is to insert two spades or forks from

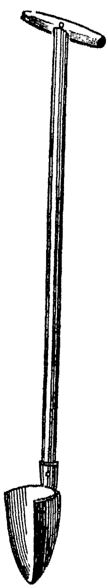


Fig. 55.

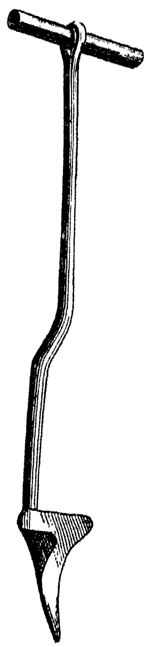


Fig. 56.

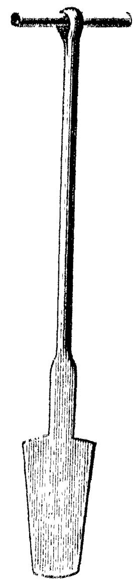


Fig. 57.

opposite sides, in a slanting direction, so that they meet, or nearly so, underneath the plant; both spades are then bent back and the plant lifted.

Sometimes hoes, ordinary or pronged, are used, but they are inferior to spades or forks for lifting plants.

Pulling up plants injures the roots and should be avoided.

10. Pruning Plants.

As a general rule, plants should not be pruned unless it is absolutely necessary. Every cut produces a wound, exposing

the plant to disease, which may ultimately render the tree unfit for the purpose for which it has been grown. Research has shown that the unhealthy condition of timber trees may be due to spores of fungi entering their tissue through wounds received at a very early age.

Where woods are grown for fuel, or treated under a short rotation, the above consideration is of comparatively small importance; in the case of timber plantations, however, which require long periods of time to mature, the forester will do well to pause before he proceeds to prune his plants. Healthy plants of moderate size can be produced at such a low cost that it is far preferable to throw away badly-shaped plants, than to prune them and risk the introduction of disease. In the case, therefore, of small and moderate-sized plants pruning should be avoided. Such plants should be so grown that a compact root system may be produced which does not require pruning.

Where large plants are used, pruning may be necessary; its execution depends on a variety of circumstances, of which the following may be mentioned :—

a. Shape and Condition of Plants.

In the case of plants of a normal shape, especially if the root system and crown are in proper proportion, pruning is not necessary. In the reverse case, either the root system or the crown and even the stem may be reduced in extent; of two leaders, one may be removed, abnormally strong side branches shortened, inconveniently long tap or side roots reduced. The pruning of one part may necessitate the pruning of the other, so as to establish a due proportion between them; if, for instance, the root system has been pruned but not the crown, portions of the latter may not receive sufficient nourishment and dry up. Normal plants frequently require pruning, because the root system has been injured in lifting them.

b. Species.

There is a great difference in the treatment of plants of different species; some stand pruning better than others, both as regards the replacement of the pruned parts and the extent to which they are exposed to disease.

On the whole, conifers stand pruning badly. Larch is perhaps an exception, also deodar and *Pinus longifolia,* though they cannot be pruned to the same extent as broad-leaved species. The latter recover much quicker, especially species with a strong reproductive power after injury, such as willow, poplar, oak, hornbeam, elm, alder. Beech and birch, on the other hand, are less vigorous in this respect. Teak stands much pruning of the crown, but less of the root system.

c. Locality.

Under favourable conditions of soil and climate, pruning is less injurious than in the reverse case. On fertile fresh soil, a comparatively small root system suffices to fulfil the necessary work of assimilation, and fresh organs are formed in a short time; on dry poor soil, pruning of the roots must be much more restricted.

d. Manner of Pruning.

In all cases, a clean cut should be made; it should be somewhat slanting and not at right angles to the branch or root. Where a whole branch is taken off, the cut should be flush with the stem to insure quick healing by occlusion; if it is only shortened, the cut should be made just above a strong bud.

The operation may be performed with a pruning knife, pruning scissors, shears, or a light hatchet; in the latter case, the plant should be placed on a firm support during the operation, so as to injure the remaining wood and bark as little as possible.

11. Protection of Plants in Transit.

During transit, plants must be protected against drying up and frost, and this refers more particularly to the root system; a few minutes of exposure often suffices to kill the finer roots. The method of protection depends on the kind of plants, the time during which the plants are in transit, the species, and the climate to which they are exposed; the drier the latter, the more carefully must the plants be protected.

Ball plants possess already a good protection in the lump of earth in which the roots are imbedded. For transport occupying not more than one day, the balls should be packed close together to prevent their drying and the earth from being shaken off. Only in rare cases are such plants carried over long distances, the cost being too great.

Plants without a ball of earth should at once be protected. This is best done by dipping the roots immediately after lifting into soft mud, which forms a thin layer over them; the plants should then be tied together in bundles of convenient size. For transport over short distances, which occupies not more than one day, the bundles should be placed in baskets, wheel-barrows, carts or waggons, according to circumstances, the roots being surrounded by, or imbedded in, moss, grass, or earth. If the weather is dry and the sun shining, some cover may also be provided, to prevent the drying up of the foliage. The moss or grass used to cover them should be moistened, and this process may be repeated from time to time during transit. If the transport extends over several days, further precautions are necessary. The small bundles are, in that case, bound together into large packages, by arranging the plants so that the roots are all on one end, well wrapped in wet moss, grass, &c., and then secured by withes. The whole package is covered with matting. In the case of small or middle-sized plants, two layers are packed together with the roots in the centre and the crowns outwards on both sides. Plants packed in this manner keep fresh for a week, provided they are so packed that no heating takes place.

On arrival at their destination, the plants should at once be unpacked, and either planted out, or heeled in (bedded in earth) until they can be planted. The heeling in is best done by arranging the small bundles in trenches and covering the roots and part of the stem with moist soil. If necessary, shelter against the sun or dry winds may also be provided, and the plants may be watered.

12. Preparation of the Soil.

Only in very rare cases does the soil require complete working before planting, and in such cases it is done by one of the methods indicated for direct sowing. As a general rule, planting requires only working at the spots where the plants are inserted into the ground, or none at all. In silvicultural operations conducted on a large scale, the worked area of a planting spot ranges upwards from a few square inches, and rarely exceeds 2 or 3 square feet. The actual method of working the soil depends on the methods of planting; hence it will be described when dealing with the latter.

B. The Raising of Plants.

Plants can be procured either by purchase or home production; in the latter case they can be taken from existing woods, or raised in temporary or permanent nurseries. Although, in the majority of cases, plants are purchased or produced in home nurseries, the third method may in certain cases be admissible, hence the subject will be divided as follows :—

(1.) Purchase of plants.
(2.) Plants taken from existing woods.
(3.) Raising plants in nurseries.

1. Purchase of Plants.

In former times, the necessary plants were, as a general rule, grown at home, and this is still the case in many countries. In Great Britain, and now also on the Continent, a highly developed industry of raising plants for sale has been established, and in the former country by far the majority of plants

are now-a-days purchased from nurserymen. This system is very convenient, since the planting operations are not interfered with by want of the necessary planting material. Railway communication, also, is now so extended and rapid that most important species of forest plants can be sent to any part of the country without serious risk to their health and vigour. The art of raising strong hardy plants has been so fully developed by nurserymen, that almost any description of plants is procurable at short notice.

Under these circumstances the purchase of plants is quite justified in Great Britain and in a few other countries, provided the forester takes care that he receives only good healthy plants of the description indicated on page 178. He must, more especially, see that he receives plants with a properly developed root system—that is to say, one which is full and compact, but at the same time of a natural shape. It has of late years become the practice to lay down the seedlings, when they are pricked out, into shallow trenches, involving the bending over of the root system to one side; the result is a bushy altogether lop-sided root system. If such plants are put out into the forest, they take years to recover a normal, healthy shape of the root system, and until this takes place they have only a limited hold on the ground, and are liable to be blown over by strong winds. This drawback is often maintained up to middle age, if not longer. Unless nurserymen give up that practice, they must be prepared to see landed proprietors revert to the system of home nurseries; indeed this has been done already.

In selecting plants, care should be taken that they are suited to the locality where they are to be planted. For fertile localities at low elevations, well grown tall plants are desirable ; for poor soil, especially at high elevations, short sturdy plants are preferable. It is generally considered best, if no great differences exist between the soil and climate of the nursery and of the locality where the plants are to be put out, though this idea is frequently overdone.

2. Plants taken from Existing Woods.

Where operations are conducted on a small scale, and nursery plants are not available, the planting material may be obtained from existing young woods, such as natural regenerations or sowings. In such cases, the plants are taken from the parts which are too thickly stocked, and consequently they are generally indifferently developed; they are frequently slow in coming on after transplanting, and rarely yield good results.

3. Raising Plants in Nurseries.

Where plantings are conducted regularly on a large scale, plants may be raised in home nurseries; and even if the plants are purchased from nurserymen, it is desirable to have a nursery at home, where seedling plants can be pricked out, or reserve stocks kept until they are wanted.

Nurseries may be temporary or permanent; the former are used for a few years only, generally to yield the material for the planting of a particular locality, when they are abandoned and a new nursery laid out elsewhere; permanent nurseries are used for a long series of years. Each has its advantages and disadvantages. In the case of temporary or shifting nurseries, the cost of transport and the risk of damaging the plants during transit are smaller; on the other hand, the cost of laying out is greater, as it recurs every two or three years, and they do not, as a rule, yield equally good plants. Temporary nurseries can be established in localities of the same description as those where the planting has to be done; hence, they may be desirable where distinct zones of vegetation occur, especially in mountainous districts, also where the plants are to be put out with balls.

Permanent nurseries require to be manured from time to time, but they yield better plants; they are preferable in the majority of cases, especially in more level districts, where large numbers of plants are required year after year, and

where the transport is fairly easy and cheap. There is practically no difference in the treatment of temporary and permanent nurseries, except that in the latter case all arrangements are of a more lasting nature.

a. Choice of Site.

The site should be favourable for the growth of the particular kinds of plants which are required. If only one species or a few of similar requirements are wanted, a site can be chosen which agrees with their special requirements as regards soil and situation. In the majority of cases, however, plants of differing requirements are to be raised, and in such cases it is best to choose a site of average conditions.

The most suitable soil is a fresh sandy loam, or loamy sand. Heavy clay should be avoided, as it is less suitable than even a light sandy soil. Good depth and a suitable degree of porosity are essential, as they insure a more even degree of moisture. On the whole, good physical qualities are of more importance than richness, as a deficiency of the latter can be made good by manuring.

As regards situation, the site should, if possible, be in the centre of the area where the planting has to be done; but if no suitable locality is there available, it is desirable to go to some distance in search of it. The site should be accessible and easy of control. A gentle slope is best, or an elevated level plain; in either case, it should not be exposed to danger from frost, especially late spring frost, fairly sheltered, but open to the free circulation of air. The aspect depends on circumstances, especially latitude and elevation. In temperate Europe, the least favourable aspects are eastern and south-eastern on account of late frosts, and southern and south-western on account of the rapid evaporation of moisture.

The idea that the soil of the nursery must be of the same or a similar description as that where the plants are to be planted, is not borne out by experience. Well developed vigorous plants raised on favourable soil do best, even on

inferior soil. Nor does a moderate difference in elevation necessitate the establishment of separate nurseries.

The site should, if possible, be so chosen that water can be led on to it from a spring or stream, or that at any rate water may be found at a reasonable depth for the construction of a well.

b. Area.

This depends on the species, the method of treatment, the number of plants, whether they are pricked out or not, and the age at which they are finally removed. It is clear that no general rule can be given. By way of illustration, it may be mentioned that for raising two-year-old seedlings of spruce, the area of the nursery should be about $\frac{1}{2}$ per cent. of the area to be annually planted at 4 feet apart; if the two-year-old seedlings are pricked out, and remain for another two years, the nursery should comprise at least 4 per cent. of the area to be planted annually.

Where broad-leaved species are raised, such as oak or beech, the percentage is higher. It increases very rapidly with the age of the plants; for instance, in the case of twice pricked out oaks, which are planted out at the age of 9 years at 10 feet apart, the area would amount to not less than 30 per cent. of the area to be planted annually.

c. Shape.

Whenever a free choice is possible, the shape of the nursery should be that of a square or rectangle, because it admits of a regular rectangular shape being given to the beds without waste of area.

d. Fencing.

The nursery must be thoroughly protected against cattle and game by fencing it substantially. The nature of the fence depends on circumstances (see page 134); it may consist of a stone wall, wooden or wire fence, living hedge, etc.; stone walls are liable to interfere with the free circulation of the air,

while living hedges take some years to grow. Of late years, wire fences, if necessary combined with rabbit netting, have grown in public favour.

e. Draining.

This will, as a rule, not be necessary, as soil which requires draining should not be chosen for a nursery. Where no other site is available, the draining may be so arranged that the water is collected in a well at the lowest point of the nursery, to be used for watering during dry weather.

f. Watering.

As a general rule, watering will be required at any rate for the seed beds ; hence, the importance of choosing a site situated in the vicinity of a spring, stream, or tank, from which the water can be easily brought into the nursery. In the absence of such a supply, one or more wells must be sunk, and the water lifted.

The water can be distributed by hand, or by irrigation. The latter can be done in two ways, by percolation or by flooding, according as to whether the water stands in channels between the beds, or is allowed to cover the surface of the beds. Flooding is more effective, but it is followed by the formation of a hard crust on the surface, which requires to be broken; in the majority of cases percolation is preferable.

g. Preparation of the Soil.

It is highly desirable that the soil of the nursery should be free from stones and roots, and as finely divided as possible, in other words, it should be prepared in the same way as garden soil. The depth to which the soil should be worked depends on the species and nature of the desired plants. Where a compact shallow root system is wanted, it is best not to work too deep, and to see that the surface soil is fertile; if deep rooted plants are desired, the soil must be worked to a considerable depth. If one or two kinds of plants are to be

raised, their special wants can be considered in the first cultivation of the soil; as a rule, however, more species, and those of varying requirements, are wanted, which it is convenient to raise in any part of the nursery. Under these circumstances, it is generally preferable to prepare the whole nursery for the production of any kind of plants. In a country with a climate like that of Britain, the best plan is to trench the nursery to a depth of 2 feet. During this operation, all stones and roots should be removed, the land levelled as far as practicable, or terraced on sloping ground, and the best earth kept near the surface. The most suitable time for trenching is autumn, so that the ground may lie fallow over winter and be exposed to the effects of frost and of the winter rains. In the following spring, the soil should again be worked, either with plough, spade, or hoe, and harrowed so as to divide it finely. The nursery operations can then be commenced, or the ground, after manuring, be used during one season for the cultivation of a field crop, such as turnips, mangold-wurzel, or potatoes, so that the additional cultivation may produce a further division of the soil. After the removal of the crop, the ground is ploughed and left fallow over a second winter, when it should be quite ready to serve as a nursery. In the case of temporary nurseries, a more rough-and-ready method of working is frequently employed.

h. Manuring.

On good soil, plants can be raised for a number of years without manuring, but sooner or later this becomes necessary. Although the demands on the soil of a growing crop of trees are comparatively small, yet, through the uninterrupted growing and removal of seedlings, considerable quantities of various substances are taken out of it which must be replaced.

Manuring, or amelioration generally, has for its object to improve not only the chemical composition, but also the

physical qualities of the soil. If, at the outset, the soil should not be of the proper consistency, it must be improved by the admixture of sand to a stiff soil, and by that of loam to an excessively loose and light soil. At the same time, and at any rate after a few years, the soil can be specially manured. The materials which must be brought into the soil are phosphates, potash, nitrates, and next, lime, magnesia, iron and sulphur. The usual forms of manure are: *Stable manure* is perhaps the most suitable if it can be obtained at a suitable price. It not only contains nitrogen, potash, and phosphates, and other necessary substances, but it has also a most beneficial effect upon the physical conditions of the soil. Frequently, it is first converted into compost. *Phosphates* are best given in the shape of basic slag in the autumn, that is to say, some time before the beds are sown or planted. *Potash* is introduced as kainit, or as sulphate of potash; it should be given in autumn. *Nitrogen* is perhaps best given as sulphate of ammonia, generally in spring. *Lime* is wanted if the soil is poor in it; it is frequently given in connection with the preparation of compost. Other forms of manure are guano and bone dust.

The quantities of manures to be given vary much according to the nature of the soil, the species to be grown, and the length of time which the plants are to remain in the beds. Hence, it is impossible to indicate accurate quantities. In a general way it may be said that about the following quantities may be considered a suitable dressing for nursery purposes, per acre:—

Stable manure	= 80 to 100	cwts.,	or
Basic slag	= 10	,,	together.
Sulphate of potash or Kainit	5 / 20	,,	together.
Sulphate of ammonia	1 to 2	,,	together.

All such manures are, however, expensive, and with a view to recovering a part of the outlay, the soil may be used for one year for the production of a field crop immediately after

having been manured. This measure is further useful, because it gives the soil a change of crop, while it receives at the same time a thorough working. British nurserymen, as a rule, act as follows: they treat their nursery ground under a rotation of three or four years; they manure, take off one field crop, and use the soil during two or three years for nursery purposes.

The manure can be supplied by growing a leguminous crop, such as lupine, and ploughing it in instead of removing it. Such plants take nitrogen from the air which is thus brought into the soil. It is also of great importance that by their ploughing in, the soil receives a quantity of humus which has a very beneficial effect.

In many nurseries, considerable quantities of mild manures are used, such as leaf mould, compost, burnt turf, and also charcoal refuse. The leaf mould is taken from the forest, or specially prepared from dead leaves, needles, forest plants, etc., which are heaped together and allowed to decompose, generally with the addition of a certain amount of quicklime.

Compost is a mixture of humus and soil. It is generally made into heaps, some quicklime added, and then allowed to season, the heaps being turned over from time to time; it should not be used for a year or two. To prevent the compost being washed out by rain water, it is sometimes stored in pits instead of heaps.

Burnt turf is produced by cutting sods of turf, best from loamy soil, in spring, allowing them to dry, the grassy side downwards, and then burning them in heaps either alone, or better intermixed with brush wood or fagots (Fig. 58).* In constructing such a heap, some brushwood is placed in the centre (*a*) and covered with perhaps four layers of sods (*b*), then comes a second layer of wood (*c*), followed by three or four more layers of sods (*d*). A narrow channel (*m*) is kept open from the wood in the centre to the circumference by

* After Heyer.

which the wood is ignited. The effect of burnt turf is not of long duration; manuring with it has generally to be repeated every year; it acts, however, very favourably upon the physical condition of the soil, somewhat in the same way as humus.

i. Laying out the Nursery.

The area of the nursery is divided into compartments of convenient size, generally of the shape of a square or rectangle. The number of compartments depends on the number of species to be grown, and the age of the plants when put out into the forest. Assuming the latter to be three years, there should be four compartments in each set,

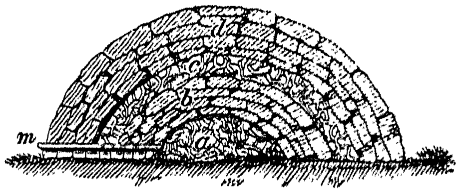


Fig. 58.

to allow each compartment to lie fallow, or be used for the cultivation of a field crop every fourth year.

The compartments should be separated by roads, which cross each other at right angles. Their breadth depends on circumstances; in most cases it is desirable to make the main roads sufficiently broad to admit carts or wagons. The roads are excavated to a depth of 6 to 12 inches, the soil being spread over the adjoining land and then filled in with a layer of macadam or coarse gravel, covered by a thinner layer of fine gravel or sand, in such a manner that the surface slopes gently from the centre towards the sides. A useful measure is to line the roads by an edging of a suitable plant (privet, box, etc.), which helps to keep them tidy.

In the case of heavy seeds, such as acorns, chestnuts, etc., the whole compartment is sometimes sown broadcast, or in

lines at such distances that a man can walk between them, and then no further division is required. In the majority of cases, however, the compartments destined for sowing are divided into parallel beds intersected by paths. These beds should not be more than four feet broad, so that a man can easily reach from the path to the centre of the bed without treading on it. The paths are of just sufficient breadth to allow a man to walk along them. Where the seed beds are to be irrigated by overflow, the paths should be on a higher level than the beds, so as to act as embankments to keep the water on the beds.

j. Sowing the Seed Beds.

The surface of the seed beds having been reduced to a fine degree of division, the seed is sown, either broadcast, or in lines or drills; the latter is frequently preferred, as it facilitates weeding. In the case of broadcast sowing, the seed is scattered evenly over the whole seed bed.

Line sowing may be done by pressing the seed individually into the ground, or by opening out shallow drills at suitable intervals, and placing the seed into these; the drills can run longitudinally over the seed bed, or crossways, the latter facilitating weeding. The depth of the seed drills depends on the species, and ranges from about ½ of an inch to 2 inches. Similarly, the distance between the seed drills depends on the slower or faster development of the seedlings and the time they are to remain in the seed beds; it varies from 6 inches to a foot. The seed drills can be made by hand, with a peg, or narrow-pointed trowel-shaped hoe (Fig. 59), or by pressing wedges or square-shaped battens into the ground (Fig. 60). In fact, quite a variety of instruments have been invented for the purpose. Fig. 60, *a*, *b*, *c*, shows three differently shaped drills. The covering of the seed is done by hand, or with the rake, or by scattering fine earth, compost, turf ashes, etc., over it to the required depth. In any case, it is desirable to

press the covering down, best by passing a light roller over the bed.

Sowing should only be done during suitable weather, that is to say, when the soil is of the desired degree of dryness. The actual method of sowing depends on the species. By way of illustration some of the methods followed in Britain are here added :—

Heavy seeds such as *acorns, sweet chestnuts, walnuts, horse-chestnuts*, etc., are generally sown in lines which are from 9 to 12 inches apart. The seeds are either sown in drills about 2

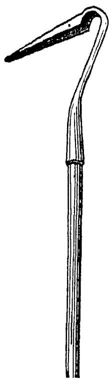


Fig. 59.

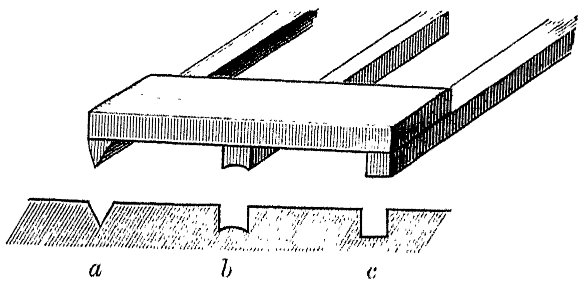


Fig. 60.

inches deep and covered by earth drawn over them with a rake ; or they are placed on the surface and then covered with earth taken from the space between the rows. In the latter case, the seed rows form slightly elevated ridges. Seeds of the above-mentioned kinds may either be sown in autumn soon after they have been gathered, or they may be kept over winter in airy places, where they are occasionally turned and perhaps also mixed with some sand.

Beechnuts are treated similarly, but the covering should not exceed $\frac{3}{4}$ of an inch ; they are sown more frequently in spring than in autumn.

Maple seed is sown soon after gathering in lines as before,

mostly on the surface and covered with soil to a depth not exceeding $\frac{3}{4}$ of an inch.

Elm seed is sown immediately after it has become ripe, at the end of May or beginning of June, generally in lines about a foot apart; its covering should consist of fine earth placed over it of a thickness not exceeding $\frac{1}{4}$ of an inch.

Alder seeds are generally sown broadcast in early spring, and covered with $\frac{1}{4}$ to $\frac{1}{3}$ of an inch of fine mould.

Birch should be sown as soon as it ripens (beginning of August), and covered with about $\frac{1}{4}$ of an inch of fine mould, or simply mixed with the surface soil.

The seeds of *ash, hornbeam,* and *thorn* are mixed with sand and kept from 15 to 18 months in a pit, where they are occasionally moistened and turned. They are sown in early spring of the second year, together with the sand in which they rested; they receive a covering not exceeding $\frac{3}{4}$ of an inch.

The seeds of *larch, spruce, Scotch pine,* and various other *conifers* are sown broadcast or in drills in spring on carefully prepared beds. Silver fir is frequently sown in autumn. They are sown on the surface and then covered with fine earth; frequently, the process consists in scraping a sufficient quantity of soil from the surface of the bed to both edges, then sowing the seed and raking back the earth from the sides towards the centre of the bed. After thoroughly smoothing the surface, a light roller is passed over the bed. The drills, if preferred, are shallow, not more than $\frac{3}{4}$ of an inch deep and filled with loose soil. A covering of $\frac{1}{3}$ of an inch is quite sufficient.

k. Quality and Quantity of Seed.

Considering the heavy expenditure involved in laying out nurseries, none but seed of the best quality should be used.

The quantity of seed to be sown on a given area depends on the species and the time during which the seedlings are to remain in the seed bed. Too dense sowing causes the

seedlings to grow up lanky, while too thin sowing involves loss of area and consequently increases the cost. If the seedlings are to go direct from the seed bed into the forest, the quantity of seed should be about one-half of that sown when the seedlings are to be pricked out in the nursery.

As to the actual quantity of seed to be sown, views differ so considerably that it is not possible to give average data. In Messrs. Howden & Co.'s nursery at Inverness, the following quantities of good clean seed are sown broadcast per 100 square feet of seed bed :—

Scotch pine	=	·6 pound.
Spruce	=	·6 ,,
Austrian pine	=	·8 ,,
Larch	=	1·0 ,,

Messrs. Howden & Co. consider it a good full crop if one pound of good Scotch pine seed produces 15,000 seedlings.

Gayer gives the following average quantities of seed to be sown in drills per 100 square feet of seed bed :—

Oak and sweet chestnut	=	·05 bushel (at 8 gallons).
Beech	=	·13 ,,
Ash and maple . .	=	·3 pounds.
Elm	=	·23 ,,
Hornbeam . . .	=	·18 ,,
Alder	=	·36 ,,
Birch	=	·41 ,,
Silver fir . . .	=	·82 ,,
Scotch pine . . .	=	·17 ,,
Spruce . . .	=	·23 ,,
Larch	=	·46 ,,
Austrian pine . .	=	·26 ,,

Broadcast sowing takes from twice to four times the quantity of seed required for drill sowing; hence, Gayer's data for conifers agree fairly well with those given by Messrs. Howden & Co.

l. Pricking out.

In some cases, the seedlings are taken direct from the seed bed to the forest; in others, they are transplanted once or several times in the nursery, before they are finally put out. British foresters call the former "seedling plants," and the latter "transplants."

Seedling plants, which are to go direct to the forest, must be grown roomy in the seed beds, so that they may develop properly; plants which are to be pricked out in the nursery may stand closer together in the seed beds.

Pricked-out plants are generally placed in rows, called "nursery lines." The soil devoted to them must be carefully prepared, though not perhaps quite to the same extent as that of seed beds.

The area required for nursery lines depends on the species, the age of the seedlings when pricked out, and the time they are to remain in the nursery; on an average it may be estimated at 8 to 10 times the area of the seed beds, provided the plants are one year old when pricked out, and four years old when put out into the forest.

Seedlings should be pricked out while young. In the tropics, the proper age is sometimes only a few weeks; in temperate Europe, generally one or two years, according to the nature of the species and the locality.

When the object is to produce large and strong plants, or a full and bushy root system, they may be pricked out a second or even a third time, after an interval each time of one, two or more years.

Plants may be pricked out at any time, provided it is done carefully, rapidly, and when the soil is fairly moist. In temperate Europe, the best time for extensive operations is early spring. Moist weather is desirable during the operation. else the plants may have to be watered. The lifting and protection of the plants during transit have been dealt with above.

The distance between the nursery lines, and between the

plants in the lines, depends on the size of the plants, their more or less rapid development, and the time which they are to remain. Ordinary two-year-old seedlings of Scotch pine and spruce, which are to remain for two years, may be placed from 3 to 6 inches apart, with a distance of 8 to 12 inches between the lines. Larch plants must be placed somewhat further apart, while for oak the distances are still greater. Roomy pricking out gives better plants, but the costs are also greater.

Messrs. Howden & Co., Inverness, generally line out the

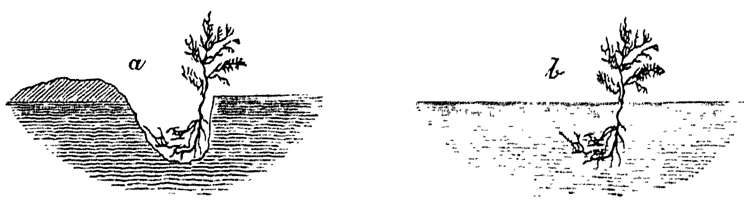


Fig. 61.

larch one year old and Scotch pine two years old. They place them 3 inches apart in the lines, with 9 inches between every two lines.

The pricking out can be done in a variety of ways according to the description of plants. The more usual methods are, either to make a separate hole for each plant with a planting peg, a small hoe, or a garden trowel, or to open trenches, into which the plants are placed at the proper distance apart. In either case, the roots should be placed into a natural position, and the soil well pressed around them.

British nurserymen, in raising plants for silvicultural purposes, proceed in the following manner :—

The soil, after having been brought into a suitable condition, is thoroughly smoothed along the whole length of the compartment, then a planting line is placed on it, parallel to one side of the compartment; then the ground is cut away with a spade along the line, so that a shallow trench is formed with one side almost vertical (Fig. 61, *a*). Against this side the plants

are placed at the proper distance apart, some earth pressed around them, then the trench completely filled up, the earth pressed down once more with the foot, and the whole smoothed over (Fig. 61, b). Then the planting line is moved on to the following row and the operation repeated. The method works very expeditiously, and it is an excellent one in principle. It has, however, become the practice to make the trenches so shallow that the root system of the plants, instead of assuming a natural position in the ground, is altogether bent to one side. The result is that the plants develop a lop-sided root system. It may be easier to put out such plants, besides saving expense, but the system is certainly not favourable to

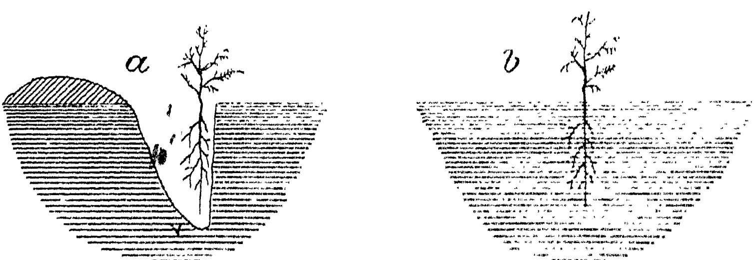


Fig. 62.

the development and stability of the trees grown by it. The author has observed, that in many cases trees 30 to 40 years old had not yet established a normal root system, and that numerous trees are blown down for this very reason. To produce really good plants, the vertical side of the trench should not be less than 10 inches deep, so that the roots go down straight to that distance (see Fig. 62). The additional expenditure is not more than about one shilling per 1,000 plants.

Of late years, a variety of machines and apparatus have been constructed with the object of facilitating the pricking out. Of these, Hacker's apparatus for the pricking out of 1 or 2 years seedlings deserves to be mentioned (Figs. 63 and 64). The illustrations explain the system. It is said to reduce the expenses very considerably.

m. Choice between Seedling Plants and Transplants.

Each of these two kinds of plants has certain advantages and drawbacks, and it depends on the circumstances of each particular case, whether the one or other is preferable.

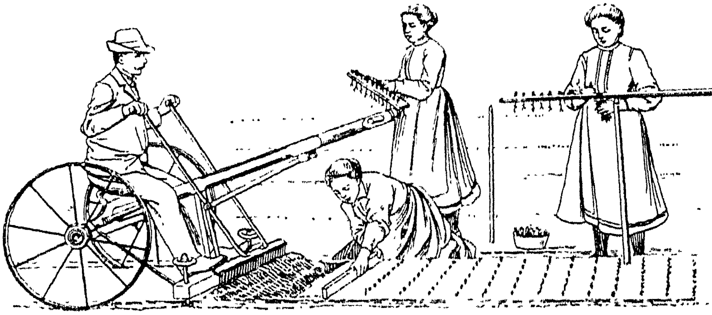


Fig. 63.—Halker's Pricking out Machine.

Pressing earth on to the roots. Removing the frame. Handing the frame. Hanging plants into the grooves of the frame.

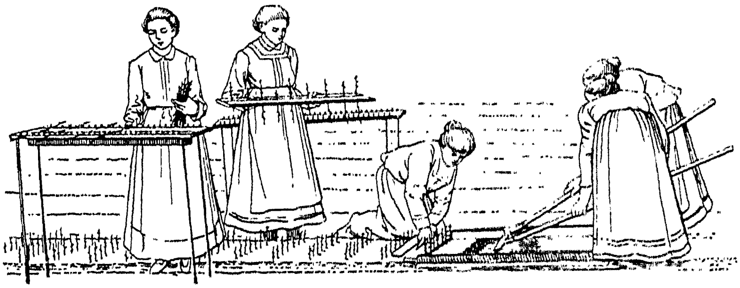


Fig. 64.—Halker's Pricking out Apparatus.

Hanging plants in grooves of frame. Handing the frame. Removing the frame. Pressing earth on to the roots.

Seedling plants are considerably cheaper than transplants, as the latter require a larger area, as well as labour in pricking out and tending. On the other hand, transplants are much superior, as they have more room to develop; especially the root system ~~becomes~~ fuller, more bushy and compact.

For planting in favourable localities, seedling plants

may do as well as transplants; in unfavourable localities, the latter are preferable; also when specially large plants are required.

The choice also depends on the species. In the case of Scotch pine and oak, seedling plants give good results; in that of most other species transplants are to be preferred.

A plan sometimes followed consists in classifying the seedling plants when, say, two years old. The best plants are put out directly into the forest, the second class plants are pricked out in the nursery, and the third class, comprising the weak and misshapen plants, are thrown away.

n. Tending Seed Beds and Nursery Lines.

The seeds, as well as the young plants, require a certain amount of tending, more especially protection against injurious influences. The details of such tending and protecting are given under the head of Forest Protection. In this place, only the more important measures directly connected with nursery work will be indicated.

(1.) The seeds must be protected against birds. These may be kept off by shooting or frightening. If this is impracticable, small seeds may receive a coating of red lead, or the beds may be protected by placing on them thorny brushwood, branches of coniferous trees, grass, etc., or nets may be spread over them, resting on supports, so as to keep them at a suitable distance from the ground. The latter have the disadvantage that they must be lifted when weeding has to be done. Wire netting, bent in a semicircle over the seed beds, is most suitable; it needs little support and lasts many years.

Mice, moles, and mole crickets often do much damage; they must be caught or poisoned. Mice may be trapped or caught in pots buried in the pathways and half filled with water: these animals are in the habit of running heedlessly along the paths, when they fall into the pots.

Earthworms do damage by dragging small seedlings into their burrows.

Hares, rabbits, etc., must be kept out by fencing with wire netting. Squirrels must be shot.

Amongst insects, the cockchafer larvæ and the wireworms are the most destructive in temperate Europe. In both cases, damage is difficult to prevent. Cockchafers are specially fond of laying eggs in clearings in the forest, such as a nursery; and if this be repeated once or twice, it may be necessary to change the site of the nursery. Almost the only way, to meet the damage in the case of grubs of the cockchafer and wireworms, is to collect them, or to kill them with gas lime.

(2.) Extremes of climate make themselves felt by frost or drought.

In the first place, a considerable fall of temperature interferes with the proper germination of the seeds, and it may injure young seedlings. Such damage is prevented by covering the seed beds with moss, grass, straw, needles, or short branches of conifers, or by erecting a temporary roof at a convenient height over the seed beds. Very delicate seedlings may be raised under glass. The covering should be removed during the day and replaced in the evening. Somewhat later on, alternate freezing and thawing may lift the young plants out of the ground; this can be prevented by covering the space between the lines with moss or sawdust. If, nevertheless, it should occur, the plants must be speedily put back into the ground, or earth must be put on the beds.

Damage by drought is prevented somewhat in the same way as that by frost, best by shades, which are placed overhead, or on the sunny side of the beds. If the dry weather should last for some time, the beds may have to be watered. This, if once commenced, must be continued until rain falls. As watering is expensive, unless it can be done by irrigation with water obtained from a higher point, it is only done when absolutely necessary. Many British nurserymen never water: they prefer taking their chance. In more southern countries, watering frequently becomes a necessity. There, also, protection

against hot winds is frequently given by shades placed on the side whence the wind blows.

(3.) Weeding should be done frequently and thoroughly. It can be done by hand, or with knives, weeding forks (Fig. 65), light two- or three- pronged hoes, the Dutch hoe (Fig. 66), etc.*

The weeding is generally accompanied by some loosening of the surface soil; but apart from weeding, periodical working of the soil between the nursery lines is highly beneficial.

(4.) If the seedlings come up too thick in the seed-beds, they may be thinned out. In doing this, care must be taken

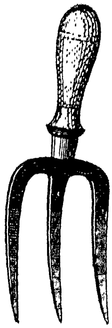


Fig. 65.

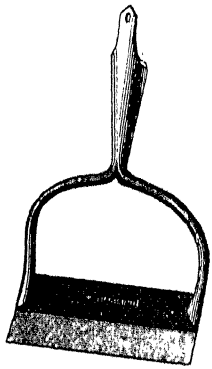


Fig. 66.

not to disturb the plants which are to remain; hence, the best plan is to cut off the weakest plants close to the ground with scissors.

C.—Methods of Planting.

The most important point in planting is to reduce the interruption of growth to a minimum, so that the plants may quickly establish themselves in their new home. How this object can be realised depends on the description of the plants, their size, and the conditions of soil and climate. To meet the different cases, various methods of planting have been elaborated, of which only the most important will be indicated.

* Figs. 65 and 66 have been taken from Brades Co.'s Illustrated Catalogue.

Whatever the methods may be, the following rules for planting are of general application:—

(1.) The plant should be placed in the ground to the same depth as that at which it stood in the nursery, allowing for a possible settlement of the soil.

(2.) The root system should receive a natural position and not be huddled together, or bent to one side.

The actual level at which the plants are placed depends on the climate and the nature of the soil. In the majority of cases, the plants are placed flush with the ordinary surface of the ground; under a dry and hot climate, they are sometimes placed in pits or trenches previously dug at a level below the ordinary surface; in wet or swampy soil, plants are frequently placed on mounds or ridges. In either of these cases, the methods of planting remain the same, except in so far as the more limited space may necessitate slight modifications. The preparation of the trenches and ridges has been described above under Direct Sowing. There is, however, a method of mound planting on ordinary soil, which will be described separately.

In planting, an opening is made in the ground into which the plant is inserted. The size and shape of the opening depend on the nature of the plant and the tool used in making the opening. Accordingly, the following methods may be distinguished:—

(1.) Planting with balls of earth.

(2.) Planting without balls of earth.

a. With hoe or spade.

b. With peg or staff.

c. Notching.

(3.) Mound planting.

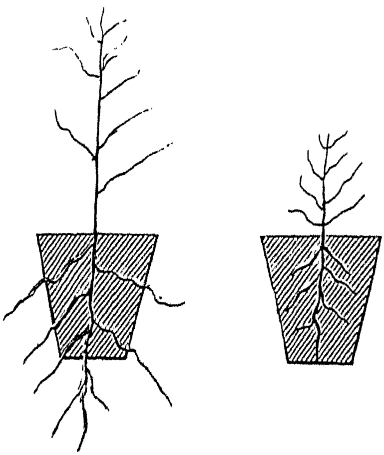
1. Planting with Balls of Earth.

Preparation of the Planting Hole.—This depends on the size of the ball. Small and middle sized plants, lifted by the circular or semi-conical spade respectively (pages 191—2), are

placed into holes made with the same instruments; such holes are wider than the breadth of the balls by the thickness of the iron, so that the plants can easily be inserted.

For plants with large balls, the pits must be considerably larger than the balls; they are made with the hoe or ordinary spade.

Putting in the Plant.—The top of the ball should be on a level with the surface of the soil, except in dry localities, when it may be somewhat lower, so as to collect an extra supply of water near the plant. The interval between the ball and the walls of the pit must be carefully filled up, either with earth, compost, turf ashes, or by pressing the soil down until the interval completely disappears. On dry soil, it is desirable to place two pieces of turf over the ball and the adjoining soil, so as to reduce evaporation and shrinking.



Bad. *Good.*

Fig. 67.

Value of Method.—This depends in the first place on the extent to which the root system is contained in the ball. If, during the act of lifting the ball, considerable quantities of the finer roots have been severed (Fig. 67), the results may be disappointing. Hence, young ball plants do better, comparatively speaking, than older and larger plants.

Secondly, a thorough touch between the ball and the walls of the pit is essential to success; it follows that ball plantings are better adapted to loose than to stiff soils; the latter, as well as the ball, shrink during dry weather, so that frequently the ball becomes completely separated, and the plant dries up.

On the whole, however, the method is one of the safest, and

is specially recommended for loose soils, frost localities, and where damage by cockchafers is apprehended; in fact, for unfavourable localities generally. It is less suited for stony or stiff soils.

The expense of planting with small ball plants is not high, but it increases rapidly with the size of the balls. In India plants are sometimes planted, in the nursery, into bamboo baskets, which are then planted out in the forest.

2. Planting without Balls of Earth.

a. Planting with Hoe or Spade.

Preparation of the Planting Hole.—After removing any covering which the soil may possess, the pit is made with the hoe, semi-circular or ordinary spade, if necessary with the pick. The size of the hole depends on the extent of the plant's root system and the nature of the soil. If the latter is rich and fairly open, the hole need not be larger than the spread of the root system. On stiff soil, it is desirable to make the pit somewhat larger and deeper, so as to give an additional amount of working and loosening. On favourable soil, the pit may be made immediately before planting; on unfavourable soil, it should be made in the previous autumn, so as to expose the earth to the effects of the winter frosts. The soil taken out of the pit should be placed in two heaps, the good soil being kept separate from the rest.

Placing the Plant.—In placing the plant in the pit, it should be held in such a manner that the root system may assume a natural position, and then the earth is gradually filled in, so as to get well round the rootlets; first pressed on gently, then somewhat more firmly, and finally pressed down with the foot. The best part of the soil should be brought into contact with the rootlets, and the worst placed on the top. Manure, such as compost, turf ashes, etc., may be given; it is placed around the roots. After the operation has been completed, the surface around the plant may be covered with turf, moss, or stones to assist in the preservation of moisture; care must

be taken that the stones do not press against the stem of the plant. In dry localities, the pit may be made somewhat deeper and not altogether filled up, so as to collect water round the plant.

Of special use during the operation is a small one-hand hoe (Fig. 68), which is used to break up the soil and to scrape it together and on to the plant.

With a view to facilitating the operation, the pit is sometimes given a vertical wall on one side against which the plant is held (Fig. 69), while the soil is placed round the root

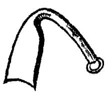


Fig. 68.

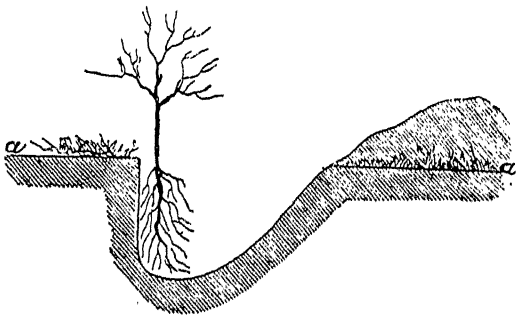


Fig. 69.

system; it has this disadvantage that the root system is pushed somewhat to one side, or flattened out.

The operation, as above described, requires two persons, best a man and a boy; the latter holds the plant, whilst the former fills in the earth. To obviate the employment of a second person, an arrangement, as indicated in Fig. 70, has been recommended. It consists of an iron rod fixed in the ground near the planting pit and bent at right angle over it. At its end it has a second elastic piece of iron, so that the stem of the plant can be pushed between the two, and the plant held in a suitable position. The advantages of the instrument are that the plant can be held in a vertical position, and that the planter has both hands free to operate with. The method can be recommended only in the case of large plants. For

operations on a large scale it takes too much time and the planting is too expensive.

During the operation of planting, manure can be added. Biermans adds turf ashes prepared as shown on page 206. The method of planting is indicated in Fig. 71. The planting hole having been made with the semi-circular spade (Fig. 55 on page 193), a quantity of turf ashes is pressed against one side

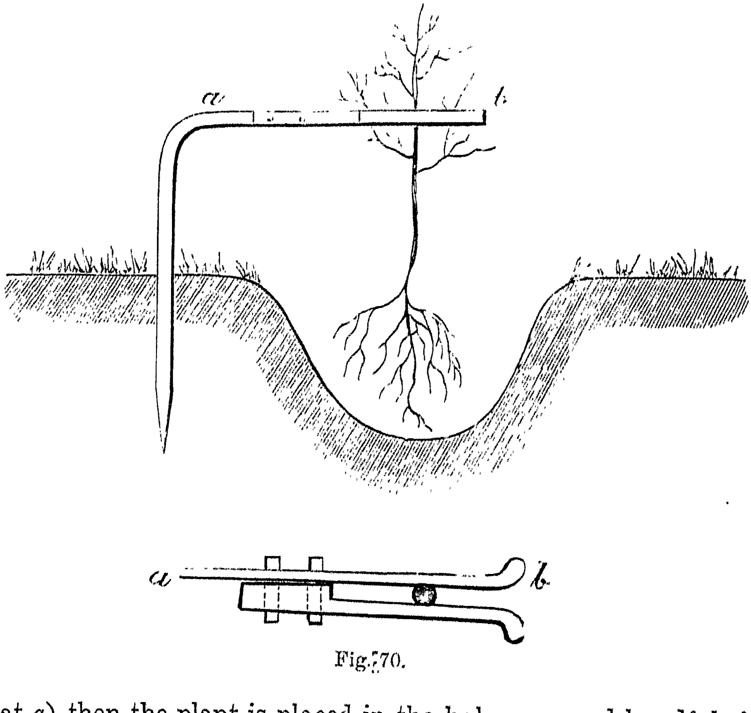


Fig. 70.

(at *a*), then the plant is placed in the hole, a second handful of turf ashes pressed against it (at *b*), then the better part of the excavated earth is filled in and placed at *c*, and the rest of the hole, if any space should be left, filled up with the less good earth. Finally the earth is pressed together by placing the foot at *d*.

Value of Method.—It is simple and can be applied to any kind of plants, or any soil, except perhaps very wet or shallow soils. It is specially adapted for large plants, particularly

those with an extensive root system. The cost depends on the size of the pits.

b. Planting with Peg, Staff, or similar Tools.

Planting with a peg is done in the case of young plants, which have not as yet developed side roots of any length. It

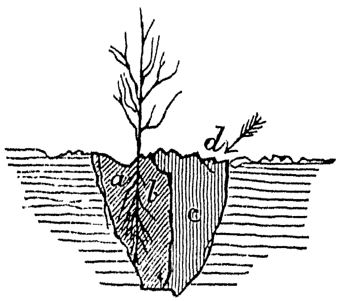


Fig. 71.

is specially adapted for the cultivation of dry localities with plants which have been raised in such a manner as to develop

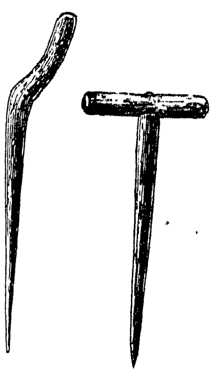


Fig. 72.

Fig. 73.

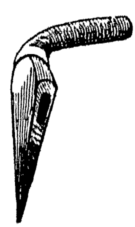


Fig. 74.

long tap roots, to bring them into contact with moisture lodging at some depth.

In order to guard against the plants being choked by weeds, it is frequently necessary to work the soil before planting, either entirely, or in strips or patches. This can be done

with a light plough or the hoe. In such cases, the area may be used for the raising of a field crop before planting.

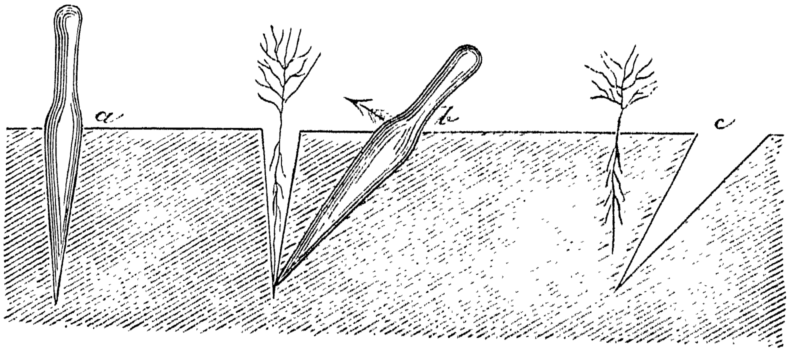


Fig. 75.

Pegs of various shapes are used, such as the ordinary planting pegs (Fig. 72), the planting dagger (Fig. 73), Buttlar's iron (Fig. 74), etc. The planting peg is constructed of wood; Fig. 73 consists of a wooden peg with an iron coating up to the handle; Buttlar's tool is made entirely of iron, the handle being covered with leather; it weighs about seven pounds.

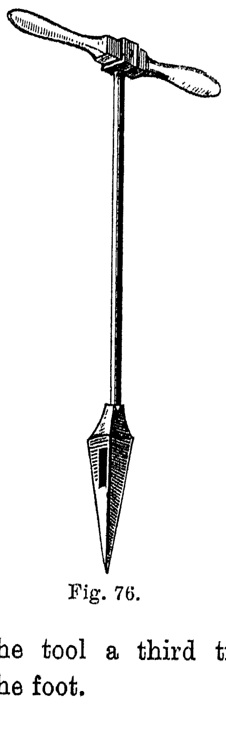


Fig. 76.

When using any of these tools, the planter holds a bundle of plants in one hand and the tool in the other; he inserts the tool into the ground (Fig. 75, *a*), takes a plant out of the bundle, holds it between two fingers, withdraws the tool, inserts the plant into the hole, re-inserts the tool in a slanting position (Fig. 75, *b*), and presses earth on to the plant by pushing the peg towards it. The second hole thus produced (Fig. 75, *c*) can be filled up by inserting the tool a third time, or by pressing earth into it with the foot.

In these plantings, the root should go down straight into the hole, and not be doubled up. To facilitate the operation of insertion, and to protect the fine roots against drying, they are frequently dipped into soft mud as soon as they have been lifted.

The method is cheap and of great despatch, especially if it is not necessary to work the soil beforehand. It is specially adapted for light sandy soil, less for stiff soil, or for a locality which is likely to be overrun by weeds. The plants should

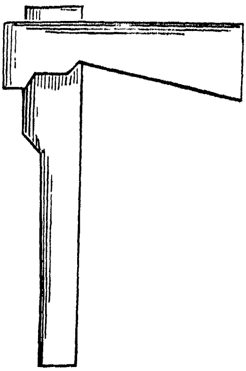


Fig. 77.

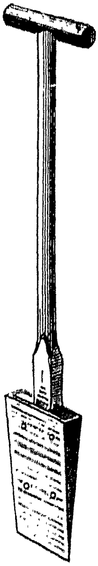


Fig. 78.

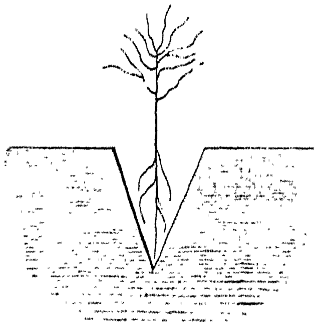


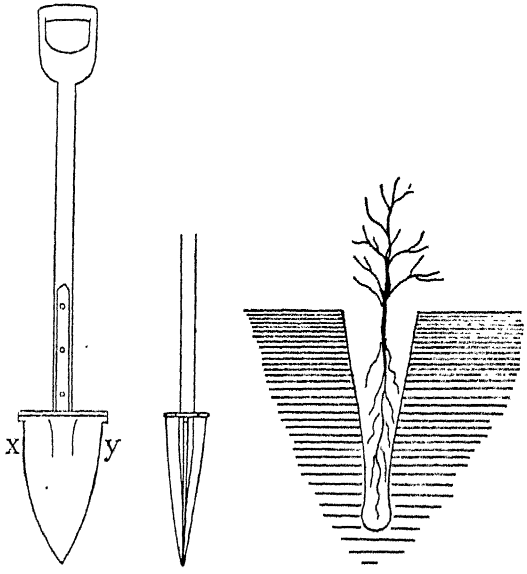
Fig. 79.

not be more than two years old, or else they will have developed too long side roots. Only seedling plants should be thus planted.

Where deeper holes are required, or on stony soil, the planting staff (Fig. 76) may be used. It is a much heavier tool, weighing about eleven pounds, and two men, or a man and a boy, are required for the operation, one making the holes and the other inserting the plants.

c. Notching.

This method differs from planting with a peg in the shape of the planting hole, which is that of a notch. The tools ordinarily used are the planting hatchet (Fig. 77), the notching spade (Fig. 78), and the ordinary spade. The hatchet is inserted into the ground with one hand and pulled out again, thus producing a notch, in which the plant is inserted; the



a b d

Fig. 80.

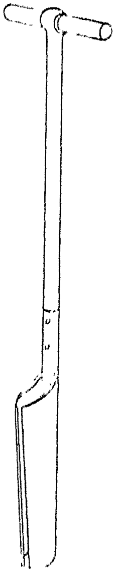


Fig. 81.

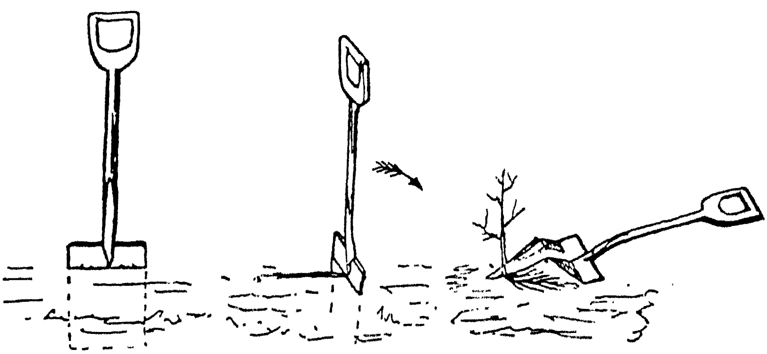
c

notch is closed by knocking the adjoining earth into it with the thick end of the hatchet; finally the soil is pressed down with the feet.

The notching spade is wedge-shaped, and after insertion into the ground, an enlarged notch (Fig. 79) may be produced by swaying the spade to and fro. The tool requires two persons, one making the notches, and the other inserting the plants, filling in, and pressing down the earth with his feet. The common spade can be used in the same way as the

notching spade, but a much better shape is that exhibited in Fig. 80 (*a*, front view; *b*, side view; *c*, section through, *x—y*). It is perfectly straight, with a sharp point which easily penetrates into the soil. In using this spade, the notch generally has the shape shown in Fig. 80 *d* (exaggerated). The plant, after insertion into the notch, is securely fixed in the ground as indicated in the case of planting with the peg (Fig. 75). This spade is no doubt the best tool which has been constructed for vertical notching.

On stiff soil, the holes for seedling plants may be made with



a *b* *c*

Fig. 82.

a hollow spade, like Fig. 81. It is not necessary to remove the ball of earth from the spade by hand; by inserting the spade for the purpose of making a second hole, the ball of earth, taken from the previous hole, is ejected at the top, and can be used to fill up the hole afterwards. The plant is inserted as before, and the hole is filled up and the soil pressed down firmly by means of a peg and the feet.

In Britain, notching is done in a somewhat different way, generally with the ordinary spade, so as to produce a T-shaped or a triangular notch, mostly the former. The spade is inserted into the ground (Fig. 82, *a*), and withdrawn; then it is a second time inserted at right angles to the first insertion and at one end of it (Fig. 82 *b*); next the handle is

bent backwards, thus raising and opening out the edges of the first notch (Fig. 82, *c*); then the plant is slipped in from the blade of the spade towards the far end of the first notch, the spade withdrawn and the soil pressed down with the feet, so as to cause the notches to close completely. The operation requires two persons, a man and a boy.

The merits of ordinary notching are very much the same as planting with a peg. As regards the British method of notching, it must be noted that the root system obtains an altogether unnatural position, it being completely pressed to one side (compare Fig. 61, *b*, on page 212). It has already been pointed out that often many years pass before this drawback is overcome. The system as practised in Britain can yield satisfactory results only under a favourable climate and in the case of certain species. It is chiefly employed in planting Scotch pine and larch plants two to four years old.

3. Mound Planting.

Apart from wet and swampy localities, planting is sometimes done on mounds, instead of in pits.

The mounds are formed either by scraping together the ordinary soil, or by depositing a basketful of specially prepared soil at regular intervals. The plant is inserted into an opening produced in the centre of the mound, and then the soil pressed round the roots until the mound has been re-formed. Finally the mound is, whenever practicable, covered with turf, to protect it against rapid drying. For this purpose, two pieces of turf are placed, one on the shady side (*a*), and the other on the sunny side (*b*), so that the latter overlaps the former (Fig. 83). In the absence of turf, stones may be placed on the mound.

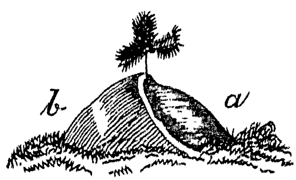


Fig. 83.

The method is only suited to plants with a shallow root system, if the mounds are to be of moderate size. It has

yielded good results on gravel or hard clay, where the striking of the plants under ordinary planting would have been doubtful. The expenses are higher than in the case of pit planting, but not by very much, since the method contemplates only small mounds.

Where mound planting is adopted against an excessive degree of moisture in the soil, the mounds must be considerably higher and larger than in the method just described. The expenditure is further increased if the planting is done on continuous ridges, prepared as described on page 143.

D. Planting of Slips, Layers and Suckers.

Plants of these kinds are used in the case of species which do not readily seed, or the seed of which germinates indifferently, or for the purpose of obtaining at once plants of some size. Such methods are only auxiliary in temperate Europe, except in the case of willows and poplars.

1. Slips.

A slip or a cutting is a rootless plant, which consists of a piece of young green wood taken from the stem or a branch of a rooted plant; when inserted into the ground, it develops roots and crown. Poplars and willows are grown in this way.

Slips may retain the leading shoot or be truncated. The former consist as a rule of stool shoots; the latter can be taken from stool shoots or from the branches of older trees, their length differing from a few inches up to ten or more feet.

In some cases, slips are in the first instance placed into nurseries, until they have become rooted, but they are generally planted out at once in the forest. The insertion into the ground can be done in various ways, such as placing the slips in furrows and covering them by drawing a second furrow with the plough; or they may be placed in ditches, trenches, pits, or each slip simply pushed into the ground to the required depth.

When entire slips are used, only the lower portion is inserted into the ground; of truncated slips only a small part remains above the surface. In order to ensure striking and a proper development, the ends of the slips should be cut sharply and smoothly in a slanting direction, and each truncated slip must contain some buds, of which at least one, or better several, must be above ground. It is also essential that the bark should not be injured at the ends; hence, pushing the slips into the ground without a previous opening is only admissible in very loose soil; in all other cases they should be planted with a special iron dibble.

The best time for planting slips is early spring, shortly

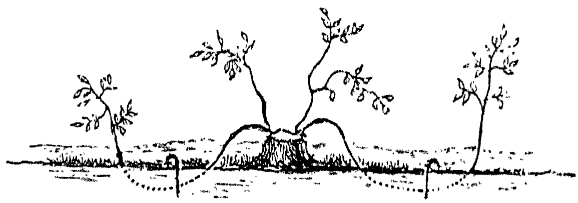


Fig. 84.

before the buds begin to swell, though, under favourable circumstances, the slips can be planted at other times, even during the growing season. The roots formed after planting come from the callus produced at the lower end or from the lenticels in the bark.

In England, the stools of osiers are recruited by slips, which are mostly entire; they are planted immediately after the osiers have been cut, usually in December. On the Continent, truncated slips are used in preference.

2. Layers.

Layers are branches, or stool shoots, which have been bent down and partly buried in the soil; they develop roots at the buried portion, and when this has taken place, they are severed from the mother tree and represent independent plants ready to be put out. The formation of roots may be expedited by

removing some of the bark of the layer below ground on the side of the parent tree.

Where large numbers of layers are required, the most suitable plan is to produce stools which send out numerous shoots. Each of these shoots is then bent back and fastened into the ground, where it remains until rooted (Fig. 84). In England, lime and elm are generally propagated in this manner.

3. Suckers.

The root, from which the sucker has sprung, is cut through, clean and slanting, on both sides of the base of the sucker, the latter lifted out of the ground and put out into the forest. The method is rarely used, as disease is likely to be introduced through the cut ends of the root.

In some cases, pieces of roots are planted out which produce roots and shoots.

Note.—Grafting and Budding, being outside practical silviculture, have not been dealt with in this volume.

CHAPTER III.

NATURAL REGENERATION OF WOODS.

Natural regeneration can take place by seed, or by shoots and suckers. Accordingly, the subject may be divided into two parts. Regeneration by seed is applicable to all species; that by shoots and suckers applies only to broad leaved species, since the power of reproduction of conifers by shoots is either absent altogether, or at any rate so feeble that it is useless for silvicultural purposes.

SECTION I.—NATURAL REGENERATION BY SEED.

By natural regeneration is understood the formation of a new wood by the natural fall of seed, which germinates and develops into a crop of seedlings. The trees which yield the seed are called the *mother trees;* they may stand either on the area which is to be re-stocked, or on adjoining ground. Accordingly a distinction is made between—

(A.) Natural regeneration under a shelter-wood;
(B.) „ „ from adjoining woods.

A. Natural Regeneration under a Shelter-wood.

The area is stocked with seed bearing trees, and the new generation springs up under their shelter; for some time, at any rate, the area under regeneration bears the new and part of the old crop.

The system is that which occurs in primeval forests. When a tree falls from old age or other cause, and an opening is thus formed in the cover overhead, the seeds falling from the adjoining trees germinate and develop into seedlings; these grow up under the shelter of the older trees or between them,

until they in their turn become mother and shelter trees. In this manner, primeval forest, if undisturbed, goes on regenerating itself for generations. The process is a slow one, as the young crop will develop only when sufficient light is admitted by the fall or death of the old trees. In silviculture, it is accelerated by the artificial removal of a portion of the old trees when they have become fit for economic purposes. By degrees, modifications have been introduced, which have led to a number of distinct methods. Of these, the following demand special notice :—

(1.) *The Selection System.**—The age classes are evenly, or approximately so, distributed over the whole area of the forest. Throughout its entire extent the oldest, largest, and diseased or defective trees are year after year, or periodically, removed, followed by the springing up of new growth in small patches or single trees.

(2.) *The Group System.*—The age classes are distributed over the forest in groups of moderate extent. The oldest groups are regenerated first, then the next oldest, and so on, until the whole forest has been gone over. Some modifications of this system have been introduced, which will be explained further on.

(3.) *The Compartment or Uniform System.*†—The age classes are so far separated that each occupies a distinct portion of the area, representing an even aged, or approximately even aged, wood. Each wood comprises one or more compartments, and either the whole, or one compartment at a time, is regenerated uniformly over the area, so that the old crop is replaced by a young, fairly even aged wood.

(4.) *The Strip System.*—This is a modification of the compartment system, each compartment being divided into a

* The term *selection system* was introduced in India ; it is perhaps not an ideal term, since a certain amount of selection is practised in all systems ; it has been retained, as none better is at present available. The system is called *Femelbetrieb*, or *Plänterbetrieb*, in German, and *Jardinage* in French.

† *Schlagweiser Betrieb* in German, and *méthode par coupes successives* in French.

number of strips. As it differs from the compartment system in some respects, it will be dealt with separately.

(5.) *Combination of the Group and Strip Systems.*

The limits between the several systems are not always clearly defined, as will be seen further on, but there are certain general conditions of success which hold good for all. Amongst these the following may be mentioned :—

(1.) The mother trees must be capable of producing good seed in sufficient quantity.

(2.) The soil must be in such a condition that it forms a good germinating bed.

(3.) The young seedlings must have sufficient light to grow up, and yet, if tender, they must be protected against external injurious influences.

(4.) The fertility of the locality must be duly preserved by protecting the soil against the excessive action of sun and air currents.

These conditions, if not naturally existing, must be produced by timely and judicious interference. The measures adopted for the purpose consist in—

(*a.*) Cuttings so executed that they produce the desired conditions.

(*b.*) Artificial preparation of the germinating bed, if this should be necessary.

The several systems comply with these conditions in varying degrees. In order to bring out the general characteristics of the methods, it is desirable to commence with a description of the compartment system.

1. The Compartment or Uniform System of Natural Regeneration under a Shelter-wood.

The regeneration occurs approximately at the same time and uniformly over a whole wood, or age class, which, for convenience' sake, is here called a compartment. The area treated at one time is called the *regeneration area.* The new crop should be created, if possible, by one seed year over the

whole regeneration area; this, however, succeeds only in exceptional cases, so that, as a rule, two or even more seed years are required to complete the regeneration. As a consequence, the regeneration process may extend over a term of 5, 10, 15, and sometimes more years, resulting in a new crop which is only approximately even aged.

The cuttings are made from time to time as required, and so that the old or shelter-wood gradually makes way for, and is replaced by, the new crop, the process being as uniform as practicable over the whole regeneration area. The successive cuttings are, for convenience' sake, generally arranged into three groups, each of which represents a distinct stage, namely,—

(*a.*) The preparatory stage.
(*b.*) The seeding stage.
(*c.*) The final stage.

Theoretically speaking, the preparatory and final stages each comprise several cuttings, and the seeding stage only one, but their actual number depends on the circumstances of each case, as will be seen from the description given below.

a. Preparatory Stage.

There is a time in the life of every wood which is most favourable for natural regeneration; it occurs generally towards the end of the principal height growth, but differs somewhat in accordance with the species and the condition of the locality. That time is, theoretically speaking, the best for the process of regeneration, but other important considerations may not always permit of this particular period being taken advantage of. In many cases, the trees at that time have not reached a profitable size for economic purposes; hence, they must be allowed to grow on for a series of years, and thus pass the most favourable period. In other cases, where only small material is required, the objects of management may demand cutting over before the most favourable period for regeneration has been reached.

Every such deviation creates obstacles to successful regeneration. Either the trees are not in the best period of life for the production of good seed in sufficient quantity, or the soil is not in the best possible condition to serve as a germinating bed. It is the object of the *preparatory cuttings* to counteract these and other drawbacks, which require to be more fully explained.

i. *Preparation of a Suitable Seed Bed.*—The soil must be brought into a condition which ensures a proper germination of the seed, and enables the seedlings to reach the mineral soil with their rootlets within a reasonable time; it must be suitably porous and moist. The necessary measures to ensure this depend on the condition of the wood, and on the nature of the locality.

In the course of a rotation, crowded woods produce considerable quantities of humus, which decomposes at a quicker or slower rate according to species and other circumstances. Where, on approaching the period of regeneration, the layer of humus and leaves is so thick that seedlings cannot reach the mineral soil within a few weeks after germination, or if the humus has become acid, it must be reduced before regeneration is attempted. This is done by removing some of the trees, thus interrupting the cover to a moderate degree, and admitting the sun's rays and a more active circulation of air, which cause an accelerated decomposition of the humus. The severity of the cutting depends on the original density of the leaf canopy; dark cover overhead demands a heavy cutting, a thin cover a light cutting or none at all. It also depends on the nature of the soil; over limestone the humus decomposes rapidly, on cold heavy soil slowly. Again, the leaves of some trees decompose more rapidly than those of others.

Situation and the local climate must also be considered. Where the degree of moisture in the soil and the air is high, decomposition proceeds at a slow rate; such localities are high situations, northern aspects, moist valleys, the shores of lakes

and the sea. In all such cases, the preparatory cuttings must be comparatively heavy.

On the other hand, in localities which are liable to be overrun by a heavy crop of grass or weeds, the cuttings must be light, or else the young seedlings, if they appear at all, will be choked.

Generally, the most suitable condition for germination has been reached when the covering of the soil has been so far reduced that the mineral soil can be seen here and there through it, without being altogether exposed; the seedlings will then be able to establish their rootlets in the mineral soil at an early stage, and thus escape the danger of being killed off by a subsequent spell of dry weather. If, at the conclusion of the preparatory stage, this condition has not been reached, a portion of the humus and leaves or moss may have to be removed artificially, or mixed with the mineral soil below.

In some cases, the vegetable covering of the soil has been too much reduced by a premature interruption of the leaf canopy, so that the most favourable condition of the seed bed is past when a seed year comes, the soil having become hard and dry, or overrun by grass and weeds. In such cases, further cuttings would only increase the evil, and must therefore be omitted; a suitable seed bed is in that case secured by working the soil immediately before or after the seed falls. The working of the soil may consist merely in removing the weed growth, or in hoeing it up either entirely or in strips or patches, causing it to be broken up by pigs, raking, harrowing, or even ploughing it with a forest plough. Generally speaking, this operation is known as "*wounding the soil,*" and is considered a most important cultural measure. At the same time, it is expensive and should be executed only when necessary.

ii. *Strengthening the Shelter Trees.*—After the ground has actually become stocked with seedlings, only a certain number of the trees, which formed the original wood, will remain on

the ground to afford shelter to the young crop and the soil. If all the rest of the wood were removed at one cutting, so that the above-mentioned shelter trees were suddenly brought from a crowded into a comparatively open position, they would probably be thrown by the first gale. To avoid this, they must be placed only gradually in a more open position, so as to obtain a firmer hold of the ground. This is done by the preparatory cuttings. It follows that, from this point of view, the preparatory cuttings are of more importance in the case of shallow-rooted species and very dense woods, than under opposite conditions.

The trees which are to form the ultimate shelter-wood must be selected from the beginning; they should be healthy trees with medium crowns, likely to produce seed in sufficient quantity, in case the first seeding should fail.

iii. *Stimulating the Production of Seed.*—Placing the trees in a more open position has generally a beneficial effect upon the production of seed, but this cannot always be relied on, as frequently such a measure is followed by increased production of wood instead of seed.

iv. *Distribution of the Yield.*—If forest trees were in the habit of producing seed regularly every year, arrangements might be made to place annually a suitable area into the seeding stage, and thus distribute the cuttings equally over successive years. As, however, most forest trees produce abundant seed only after irregular intervals, it is necessary to take full advantage of every such opportunity to bring as large an area as possible into the seeding stage. If no preparatory cuttings had been made, such a treatment would lead to an excessive yield in every seed year, and little or no yield in other years. Hence, preparatory cuttings fulfil the further duty of assisting in the proper distribution of the yield.

v. *Number and Character of Cuttings.*—Whether the preparatory stage should comprise one or several cuttings cannot be determined beforehand; it depends on the circumstances of each case. Sometimes such cuttings are altogether unnecessary

or undesirable, in others one cutting suffices, and in others again, two or even more are required.

The period over which the preparatory stage extends comprises sometimes only one or a few years, at other times as much as ten or even more years. In the latter case, the cuttings should be light and frequently repeated. Generally, the cover should not be interrupted to any considerable extent during the preparatory stage, except, perhaps, towards the end of it.

In selecting the trees to be cut during this stage, a commencement is made by the removal of diseased trees, and all species not required or desired for reproduction; then trees with bad crowns are chosen, followed by those with exceptionally broad crowns, care being taken throughout that the trees destined for the ultimate shelter-wood are as evenly as possible distributed over the area, and give the shelter required for the species under regeneration.

Instead of a separate preparatory stage, the desired effect can be produced by gradually increasing the strength of the thinnings during the last third or quarter of the rotation, so as to produce by degrees a moderate interruption of the cover. In this way, the thinnings gradually assume the nature of preparatory cuttings. This method is probably the best for bringing the soil in the desired condition to act as a germinating bed, while it affords to the final crop the best possible conditions for healthy development. It requires the constant attention of the forester.

b. Seeding Stage.

If the process of preparatory cuttings has taken its regular course, it will result in the locality being gradually brought into a condition fit to produce a new crop, which springs up and occupies the ground. Such is, however, rarely the case in practice, because the seed years come at irregular intervals; hence, to avoid the risk of opening out the old wood too early, it is desirable to hold back a little with

the preparatory cuttings. When a seed year actually comes, the regeneration area frequently is not quite ready for it, and if is found necessary to make an additional cutting, called the "*seeding cutting.*" By this measure all trees are removed which are not required afterwards for shelter or the further production of seed.

It is evident that the marking of the seeding cutting should be done only when the seed is actually on the trees and sufficiently advanced to be depended on. The cutting can be made

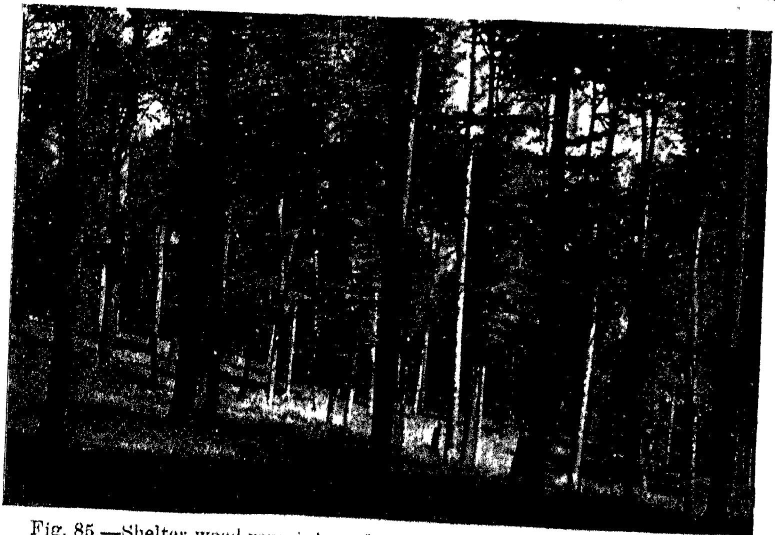


Fig. 85.—Shelter-wood remaining after the Seeding Cutting has been made.

shortly before, during, or after the fall of the seed. Cases in which this rule may be departed from are comparatively rare, for instance, on thoroughly fresh or moist soil, and in the case of a species which seeds regularly every year.

The important question at this stage is the density of the shelter-wood, which remains after the seeding cutting has been executed. That density must be such as to ensure the most favourable conditions for the further advancement of the young crop; in other words, it must afford sufficient light to the young crop without exposing it to injury by frost, drought, or excessive weed growth; at the same time, there must be

sufficient shelter left to act beneficially upon the general factors of the locality.

It will easily be understood that, apart from the species, the density of the shelter-wood depends on a variety of circumstances, such as the following:—

i. *Condition of the Locality.*—The shelter-wood should afford protection against the drying up of the soil, frost, cold winds, growth of weeds, and perhaps also against damage by insects. In localities where the young crop is threatened by one or more of these dangers, the shelter-wood must be kept dark; such localities are poor, loose, stony soils, southerly and westerly aspects, steep slopes, localities exposed to dry or cold air currents, or to great changes of temperature in spring resulting in late frosts, those inclined to a strong growth of weeds, especially calcareous soils, where wind falls are apprehended, or where cockchafers and other insects are likely to settle. Where the opposite conditions prevail, in other words on generally favourable localities, the shelter-wood may be less dark, with a comparatively light cover overhead.

ii. *Density of the Shelter-wood.*—Old trees have comparatively denser crowns than younger trees. Tall trees give less shade than short ones. Both circumstances must be considered in determining the number of trees to be left for the shelter-wood, so as to produce the desired density.

iii. *Degree of Preparation arrived at during the Preparatory Stage.*—The higher that degree, the lighter may be the shelter-wood, other conditions being the same. Whenever the preparation has been insufficient or faulty, it is desirable to keep the shelter-wood comparatively dark, because the seeding may fail or be incomplete, so that a second seed year must be awaited, before the area becomes completely stocked with a new crop.

iv. *Species.*—Above all, the nature of the species determines the density of the shelter-wood. Tender species, especially those of slow growth during youth, require a dark shelter-wood; hardy, light-demanding, quick-growing species, a much

lighter one. In the case of the latter, the distance of the shelter trees may be governed only by the distance to which the seed is naturally disseminated.

v. *Generally.*—The cover of the shelter-wood should be as even as possible throughout, whenever the conditions are uniform over the whole regeneration area; if they differ from place to place, the shelter-wood must be arranged so as to suit the changes. Along the edges of the wood, especially where exposed to dry, cold, or strong air currents, the shelter-wood should be kept dark, and it may even be necessary to provide beforehand a special shelter belt.

As already indicated, the shelter-wood should consist of healthy trees with moderate-sized elevated crowns. If trees with low crowns have to be selected, it is useful to prune the lower branches away to a height of 15–20 feet.

The time for making the seeding cutting may be, as stated above, shortly before, during, or after the fall of the seed; it must be concluded and all the material removed before the seed begins to germinate. In felling the trees, care must be taken not to injure those which remain as the shelter-wood.

The proper time has now arrived for considering whether any artificial working of the soil is required. Should this be the case, it can be done as indicated on page 164. Where root wood is saleable and the removal of the stools desirable on other grounds, the trees to be felled in the seeding cutting may be grubbed out, thus ensuring a considerable amount of working of the soil.

If the working of the soil is done after the seed has actually fallen, the latter is thereby brought into the ground. The depth of such working depends on the nature of the seed; it may be deeper for large seed, such as acorns, beechnuts, and chestnuts, but it must be shallow for small seeds. At this period, the question what to do with any advance growth must also be decided. Many foresters clear it away, so that the young crop may be as uniform as possible; others leave

really healthy groups of it to form part of the new wood; ordinary underwood of other species must be removed.

From this time forward, the regeneration area must be carefully protected against the removal of litter, cattle grazing, and grass cutting.

c. *Final Stage.*

The *final stage* comprises the period from the execution of the seeding cutting until the removal of the last part of the shelter-wood.

Fig. 86.—Regeneration has been effected. Young crop two years old.

The principal objects of the shelter-wood, after the ground has been stocked with a crop of seedlings, are to protect the young growth against various dangers and to preserve the activity of the soil until the new crop can undertake that duty. At the same time, the shelter-wood will act obstructively as regards the admission of light and precipitations, and therefore it must not be left longer than is actually required. Its removal is effected so as to meet these various requirements, by one or several successive cuttings executed at intervals of one, two, or more years. The rate at which, or the time

within which, the removal takes place depends on various considerations, such as the following:—

i. *Activity of the Soil.*—The preservation of a suitable degree of moisture in the soil is of first importance. Owing to the action taken during the preparatory stage, a suitable degree of moisture in the soil may have been imperilled. From the moment when a new crop has actually sprung up, the considerations which prompted the measures taken during the preliminary stage disappear; it becomes the duty of the forester to do his utmost to give to the soil all the shelter available after due consideration of the requirements of the young crop, and to re-establish as quickly as possible a fresh and substantial layer of humus on the ground. Until the new crop closes overhead, the old wood must provide a certain amount of shelter, and the leaves falling from it will form the nucleus of the new soil covering. On steep slopes, the remaining shelter trees help also to prevent damage by water rushing down the hill side. At the same time, the cover of the shelter-wood during the final stage is already much interrupted, and not too much must be expected from it; in some cases it may even act injuriously, as it may deprive the soil of more rainwater and dew than is preserved by the beneficial action of the crowns of the trees.

ii. *Frost.*—As regards frost, the shelter-wood does good service by reducing radiation; it is less effective against cold air currents, unless it is supplemented by a dense shelter belt, or wind break, along the edges of the wood. Most species are liable to be injured by frost during early youth, and some require protection against it for a considerable number of years.

iii. *Weeds.*—Here, again, the shelter-wood acts beneficially, by preventing, or at any rate retarding, the springing up of weeds, thus giving time to the new crop to increase in height before it has to contend with them.

iv. *Insects.*—Experience has shown that damage by insects is, in many cases, less pronounced under a shelter-wood than on clear cuttings.

v. *Light.*—As regards light, most species could dispense with the shelter-wood altogether, were it not required on account of other considerations. In the case of some species, a free admission of light is absolutely necessary shortly after the new crop has sprung up; others will bear a certain amount of shade, but only for a limited period.

vi. *Generally.*—From what has been said it will be seen that the forester has to choose between various evils when deciding on the proper density of the shelter-wood in the final stage; he must ascertain which of these contradictory demands are the strongest, and act accordingly. On the whole, he will do well to follow a middle course. Too heavy cuttings at one time are liable to cause excessive damage to the new crop.

Although, under these circumstances, it is impossible to give a definite rule for the number and strength of the cuttings in the final stage, it may be useful to give the following directions: a *lighter* shelter-wood is indicated on north and east aspects, in localities with a short vegetating season, such as high altitudes, localities not exposed to cold winds or to rapid weed growth; a *darker* shelter-wood is desirable in frost localities, on south and west aspects, and where a luxuriant weed growth may be expected.

Above all, the strength of the cuttings in the final stage must be governed by the rate at which the young crop develops. Where it is coming on well, showing strong shoots with fresh green foliage and full buds, the shelter-wood is sure to possess the right degree of density; if, on the other hand, the new crop consists of weak plants with feeble crowns, pale foliage, and thin buds, the shelter-wood requires thinning.

As regards the *severity and number of cuttings,* it may be given as a general rule that a *gradual* change from a dense to a thin shelter-wood is the best mode of procedure. Where extensive areas have to be dealt with, such a constant attention to each wood is not always practicable, and the number of cuttings must be limited and distributed at intervals of

several years. The first cutting in the final stage is generally made when the young crop is two or three years old, the others following at similar intervals according to requirements. The last cutting, or final clearing, must not be delayed too long, as a thin sprinkling of shelter trees may do more harm than good.

The *distribution of the yield* over the several years and the state of the market frequently interfere with the timely execution of the cuttings. Similarly, the occurrence of a seed year

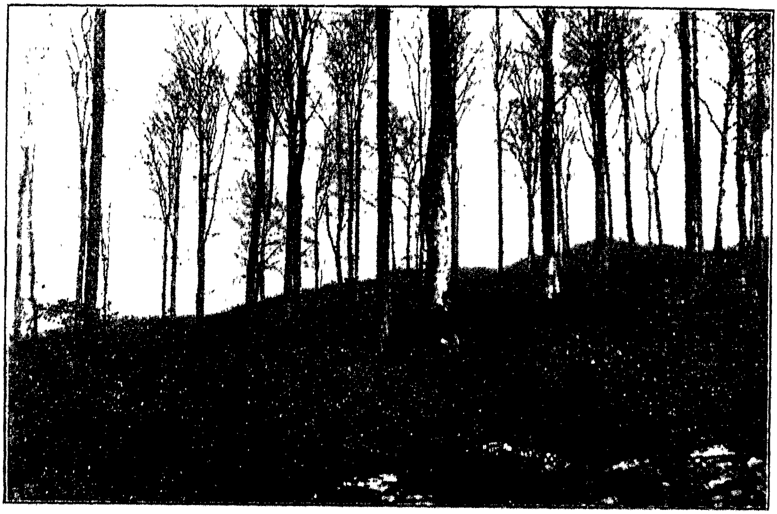


Fig. 87.—Regeneration in the Final Stage. Young Crop twelve years old.

may necessitate a suspension of cuttings in the areas standing in the final stage. These matters are not conducive to a healthy development of the young crop, but the drawback is to some extent compensated by the heavy increment laid on by the shelter trees, which increase rapidly in size and value.

The *absolute duration of the final stage* differs considerably according to species and the special conditions of each locality. In the case of some light-demanding hardy species, and in favourable localities, it may not be longer than from three to five years, while it may extend over 10, 15, and more years

in the case of tender species, in unfavourable localities, and where the object is to increase the size and value of the shelter trees in their roomy position.

In executing the fellings in this stage, special care must be taken to avoid injuring the young growth. The trees must be

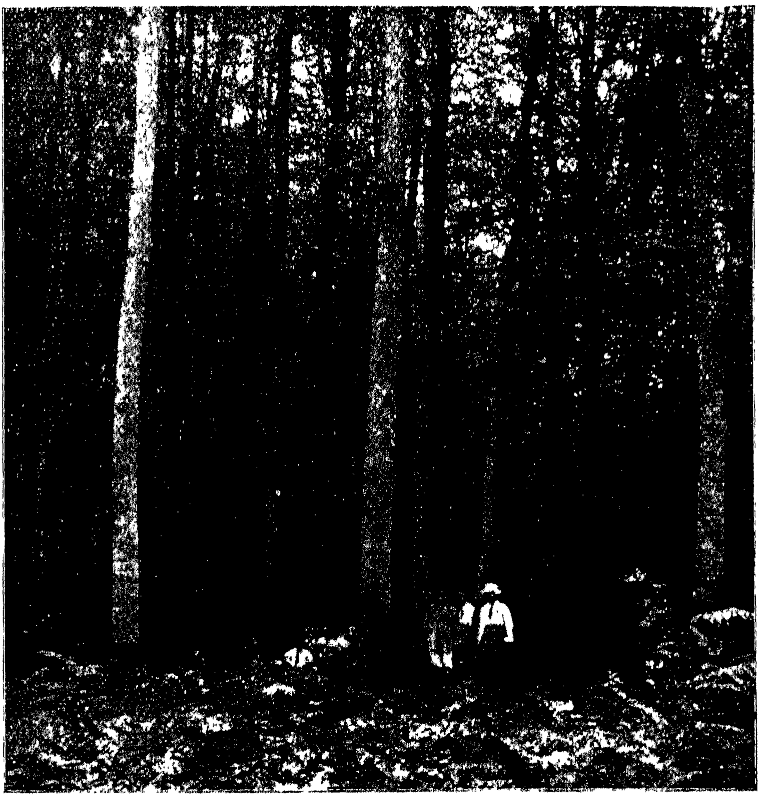


Fig. 88.—Mature Beech Wood originated by Natural Regeneration.

lopped, if necessary, before felling, and they must be thrown in that direction in which they are likely to do least damage. Fellings should not be made during frost, unless deep snow is on the ground, as the young growth is then very brittle. The material must be taken out of the wood by means which cause a minimum of damage, and, if possible, before the next growing season commences.

If, after the removal of the last shelter trees, blanks of appreciable extent exist, they must be artificially filled up by planting strong plants on them, and in some cases perhaps by sowings.

d. Marking the Trees for Removal.

What has been said above shows clearly that the success of natural regeneration by seed under a shelter-wood depends chiefly on a suitable composition of the latter during the several stages of the regeneration period, in other words, on a careful selection of the trees to be removed. Except in the case of experienced foresters, this must be carried out when the effect of the removal of a portion of the trees can be best judged, namely, when the trees are in leaf. In the case of evergreen species, the marking can be done at any time, but in woods containing deciduous species the marking should be done in summer or early autumn before the leaves fall. In carrying out the marking, only a narrow strip should be taken in hand at a time, and the business should be supervised by a competent and responsible forester.

2. The Strip System of Natural Regeneration under Shelter-woods.

As already mentioned, this system is a modification of the compartment system. Instead of conducting the regeneration process uniformly over a whole wood or compartment, the area is divided into a number of narrow strips which are taken in hand, one by one, at such intervals that generally three strips are under regeneration at one and the same time; one being in the final stage, one in the seeding stage, and a third in the preparatory stage. As soon as one strip has been completely regenerated a fresh strip is taken in hand, and so on, until the process is gradually extended over the whole compartment or wood. In the appended Figs. 89 and 90, the strip marked *f* is in the final stage, that marked *s* in the seeding stage, the one marked *p* in the preparatory stage, and the rest of the

area marked *u* is forest as yet untouched. The process of regeneration in each strip is the same as that described in the

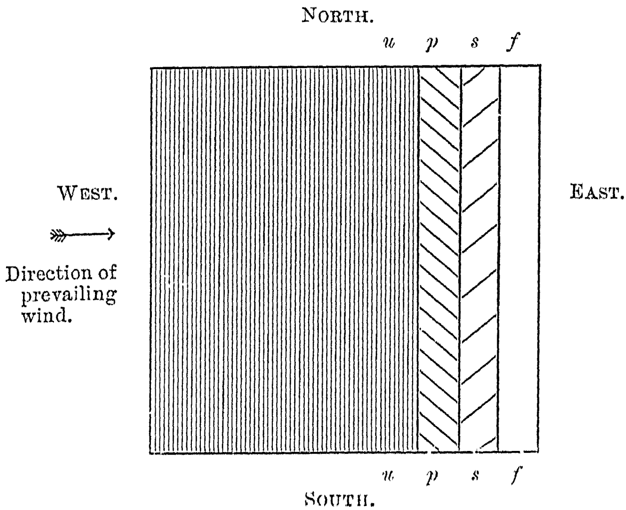


Fig. 89.

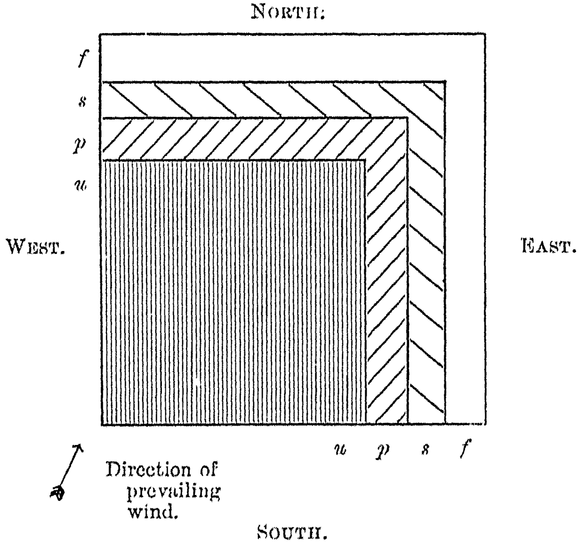


Fig. 90.

case of the compartment system; there are the three stages, one following the other.

Nothing definite can be said regarding the breadth of the strips; it depends on the species and the local conditions. Those who advocate the system say that, ordinarily, the breadth should not exceed the height of the trees. There is no limit to the length of the strips; they need not be straight, in fact they will frequently be curved.

The operation should generally commence on that side of the wood which is opposite to the prevailing wind direction; this rule may be overridden by other considerations, for instance, an unfavourable distribution of the age classes. In some cases the wood may, if necessary, be attacked in two or more places at the same time.

For the rest, little or no difference exists between this and the compartment system, except that the total area under regeneration is less concentrated in the former. On the other hand, less harm is done, if the regeneration should fail.

3. The Group System of Natural Regeneration under Shelter-woods.

If a forest is naturally regenerated under the compartment system it may happen that, after the seed cutting, the area is not, or only partially, stocked with a new crop. A second seed year must then be awaited, and in the meantime, the cover having been thinned, the soil may suffer considerably under the additional admission of light, so that it may not present a fit germinating bed when the second seed year arrives. Extensive working of the soil or artificial formation has then to step in. With the view of reducing this drawback to a minimum, foresters hit upon the idea of taking in hand in the first place only certain limited groups, scattered over the compartment; when these have been successfully regenerated, a second set of groups is taken under regeneration, and so on, until the whole compartment, or wood, has been dealt with. In practice, the system has been further modified: certain groups, as before, are taken in hand, and when these have been regenerated, they are gradually enlarged

by regenerating successive narrow bands around them, and this process is continued until the several groups merge into each other (Figs. 91 and 92). The time required for the completion of the process in each wood, or compartment, is considerably longer than under the compartment system, and generally a period of 30 or more years, according to species and local conditions, is required.

A wood, while being regenerated under this system, presents a varying picture; some parts of it have been completely regenerated, others are more or less advanced in the process, and others again are as yet untouched with a complete cover overhead. When the whole process has been completed, the young wood consists of trees varying in age by 30 or more years, according to circumstances; it is an uneven aged wood.

a. Selection of Groups.

The time when the different parts of the wood are attacked depends chiefly on the following considerations:—

i. *Advance Growth.*—In almost every mature wood, groups of young growth are found, which have sprung up, here and there, before the regeneration cuttings have been commenced; such young growth is called "*advance growth.*" Under the uniform system it is not much valued, partly because it gives the young crop an uneven character, and partly because, having stood for some time under the shade of the old crop, it is not always capable of developing into healthy full-sized trees; hence, it is frequently removed altogether to make room for a uniform new crop. Under the group system, all patches of advance growth, which are still healthy and capable of developing into full-sized trees, are carefully husbanded. They form the nuclei of the first regeneration groups; the old trees standing over them are removed when no longer required, then the groups are enlarged, as indicated above, by gradually cutting away the immediately adjoining trees in narrow bands until they merge into each other.

The question, whether groups of advance growth shall be

retained or removed, requires careful consideration. As a general proposition, it may be said that advance growth which has stood under heavy shelter for more than 20 or 25 years, should be removed, as it takes too long a period of time to recover, after it has been exposed to more light. Such

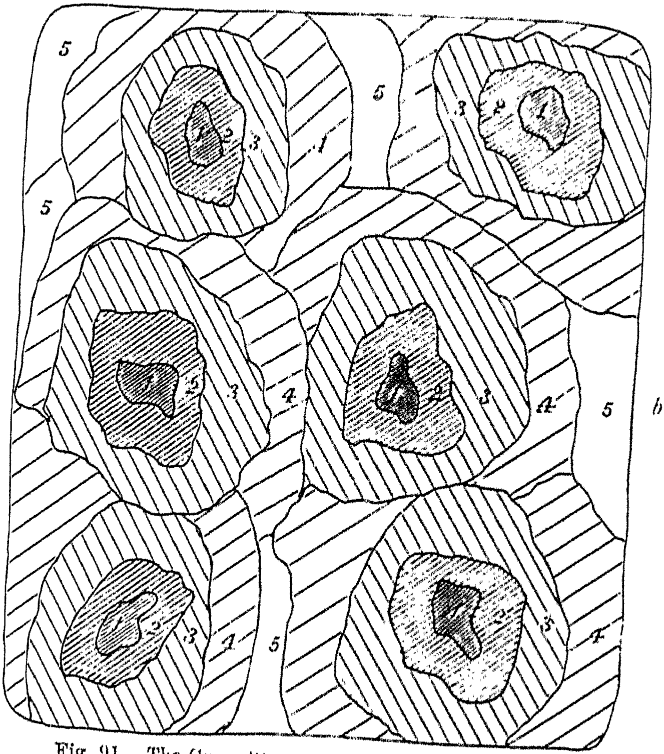


Fig. 91.—The Group System of Natural Regeneration.
1, 1, 1. Points of attack (groups of advance growth).
2, 2, 2.
3, 3, 3.
4, 4, 4. } Successive enlargements of groups.
5, 5, 5.

advance growth has, generally, vertically compressed crowns, and frequently the lower branches are already dead. Their root-system is often very shallow. Another point of importance is that the groups of advance growth should gradually fall off in height from the centre toward the circumference; otherwise they throw subsequently too much shade upon the

adjoining younger growth. Isolated individuals will grow into branchy trees of inferior value; hence, the area of the group should not be less than a certain minimum. Unless

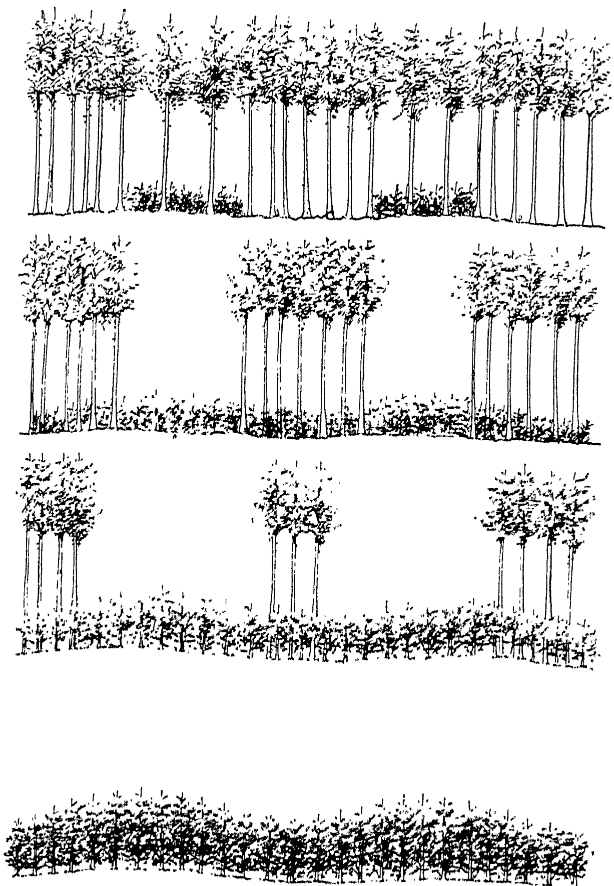


Fig. 92.—Elevation of a section along *a b* of Fig. 91, in four successive stages.

the group is still fairly young, its area should not be less than 500 square feet. Advance growth which does not comply with these conditions had better be removed. Very old advance growth can, however, first be used to act as a shelter-wood for a new crop, before it is cut away.

Speaking generally, advance growth which is more than 6

to 8 feet in height had better be removed. If it is, nevertheless, decided to retain it, then fast-growing species must be planted around it, which are likely to catch it up. Latterly, the Vancouver variety of Douglas fir has come much into favour for this purpose.

ii. *Differences of Age, Growth, Cover, and Species.*—Many old woods are naturally of uneven age. In such cases, the

Fig. 93.—Showing a group, decreasing in height from the left to the right, and also towards the foreground.

oldest parts are first taken in hand, followed by the next age gradation, and so on.

Again, certain parts, for one reason or another, have not kept pace in development with the rest, nor are they likely to make up for it. They should be taken in hand early, so as to avoid loss of increment.

Frequently, certain parts have thinned out naturally, followed by an interruption of the leaf canopy; they must be attacked first of all.

In mixed woods, groups of different species may require regeneration at different times, offering an additional opportunity for a judicious selection of the groups first to be taken in hand.

iii. *Differences in the Condition of the Locality.*—These may demand different treatment. The degree of moisture, porosity, and fertility may vary from place to place, according to the

Fig. 94.—Showing a group with its height decreasing from right to left, joining a second group on the left.

surface configuration, aspect, and the character of the soil, inviting a change of treatment and an earlier or later commencement of the regeneration process.

iv. *Generally.*—It is clear that in many woods the most suitable moment for regeneration does not occur at one and the same time over the whole area, thus offering sufficient room for a suitable selection of groups in which the process of regeneration should commence.

Where the cover overhead is still complete and no advance

growth has made its appearance, regular preparatory and seeding cuttings are made in selected spots, so as to create groups of new growth which form the centres of subsequent operations.

b. Process of Regeneration.

This is, in principle, the same as that described under the compartment system; there are preparatory, seeding and final cuttings, but they are not always quite distinct, and frequently the preparatory or seeding cutting, or both, are unnecessary. Over advance growth, for instance, the first two stages are already past, and the final stage alone remains.

Frequently, a seeding cutting or a final clearing in one group admits sufficient light into an adjoining one to act

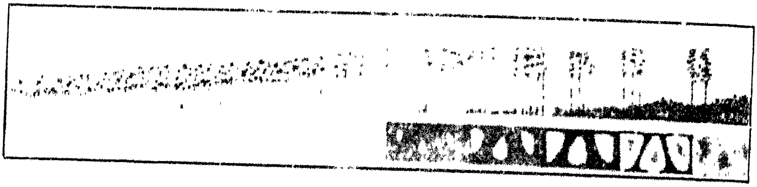


Fig. 95.—Group and strip systems combined. Regeneration commenced on the right and proceeded towards the left. The strip on the extreme right has been cleared of shelter trees.

as a preparatory cutting for it. The result is that the top of a wood regenerated in this way shows a wavy surface, as shown in Fig. 92. For further illustration, Figs. 93 and 94 are added.

4. Combination of the Group and Strip Systems.

With a view to concentrating operations, the group and strip systems are frequently combined. The compartment, or wood, is attacked at one end, generally on that opposed to the prevailing wind direction, by regenerating groups scattered over a strip; then further groups are taken in hand, going deeper and deeper into the wood. When the process of regeneration in the original groups is sufficiently advanced, the remaining shelter trees are removed in strips, so that the process presents a picture like that represented in Fig. 95.

5. The Selection System of Natural Regeneration under a Shelter-wood.

Theoretically, regeneration goes on in all parts of the forest by the removal of the oldest, largest, diseased or defective trees, wherever they are found. No part of the forest is ever at rest; advantage is taken of all seed years for the re-stocking of small holes cut into the cover here and there by the removal of one or a few trees. Of the large quantities of seed, which fall annually or periodically to the ground, only a small portion finds conditions favourable for the development of young trees; the latter are found chiefly in those parts where old trees are standing, or where the cover has been interrupted. Here little groups of seedlings spring up, which must be assisted by cuttings to afford them the necessary light. Such cuttings are the only regeneration cuttings made under the system.

When an extensive area is treated under this system, it is frequently divided into a number of blocks, one being taken in hand every year. In this way, cuttings are made in each block at regular intervals. In the beech forests of Buckinghamshire it is usual to cut according to the selection system every 7—12 years; in the Teak forests of Burma, every 20—30 years. It stands to reason that in such cases the number of trees removed must be proportionate to the interval between every two of them.

6. Comparative Merits of the Four Systems of Natural Regeneration under Shelter-woods.

Each of these systems has certain advantages and drawbacks which it is useful to bring out and compare. The result will be to show that, under a given set of conditions, any one system may be preferable to the others.

a. The Compartment System.

(1.) The business of regeneration is concentrated on a limited portion of the total area, and it is completed within

a comparatively short space of time. It follows that supervision is easier, and that it can be more effective, all other things being equal, than when the work is spread over a number of disjointed groups or strips.

(2.) The material to be removed at one time being collected within the smallest space, more satisfactory and cheaper means of export are admissible than under opposite conditions. Roads, slides, and other means of transport are of a minimum length, and their construction and annual repairs are less expensive than in the other systems.

(3.) Lateral shade is less likely to injure a young crop demanding full enjoyment of light.

(4.) Under the system, a whole wood, or compartment, is treated in a uniform manner. If the cuttings have been executed at the right time and in the right manner, the soil at the advent of the seed year being in a favourable condition for germination, extremes of climatic conditions, such as frost or drought, not causing lasting damage, nor storms having blown down the mother trees, then the result of the operation is sure to be satisfactory; in other words, a healthy and even aged young crop will have been produced. If, on the other hand, such a happy coincidence of conditions should not take place, the results may be far from satisfactory. It must be remembered that in this case success or failure extends over a considerable area, concentrated in one place; if it is a failure, only a thin cover overhead is left, under which the soil may deteriorate rapidly, whilst a second or third seed year is awaited. In some cases, the trees may be sufficiently vigorous to extend their crowns and to re-establish the cover, so that the process of regeneration can be initiated a second time and brought to a successful conclusion; but in the majority of cases this will not be possible, the soil will suffer, and artificial cultivation has to step in.

(5.) In summing up, it may be said that the compartment system is indicated in localities which are not exposed to exceptionally unfavourable climatic conditions, and which

have a soil of a fairly uniform character. Where the opposite conditions prevail, the group or selection system may be preferable; at the same time, it must not be overlooked that the drawbacks of the system can be eliminated to a considerable extent by reducing the area to be dealt with at one time in the same locality. The system is better adapted for the regeneration of pure than of mixed woods. As a matter of fact, the system is followed over the greater part of the State forests of Germany and France, where natural regeneration is adopted, though there is evidence that it will in many cases be superseded by the group or combined group and strip system.

b. The Strip System.

The system partakes of the character of the compartment system carried out on small areas; the danger of failure over a large continuous area is avoided, and the shelter trees are less liable to be blown down, but the operations are less concentrated.

c. The Group System.

(1.) The drawbacks are that the operations are scattered over a larger area at one and the same time, rendering supervision more difficult and the transport of the material more expensive. The mother trees are probably more exposed to wind fall, than under the uniform system.

(2.) The principal advantages of this system over the compartment system are :—

(*a.*) It insures a more complete preservation of the factors of the soil.

(*b.*) It affords greater security, especially in the case of shade bearing tender species, as regards the success of the regeneration, because it is carried out on small scattered areas at one time, so that failure in one does not imply failure in the others.

(*c.*) Each group can be taken in hand when the most favourable moment for regeneration has arrived.

(*d.*) The removal of the shelter trees causes less damage to the young crop, as the material can be transported through the parts of the wood not yet regenerated.

(3.) In summing up, it may be said that the group system is in its place where the conditions of the locality or of the crop change from place to place, or where extremes of climate prevail. It is admirably adapted for the regeneration of mixed woods, as it affords excellent opportunities for securing a proper mixture of the several species in the new crop.

Above all, it is specially adapted for the introduction of a more regular system of working into selection forests.

d. Combination of the Group and Strip System.

Very satisfactory results have been obtained by this combination. It possesses the advantages of the two systems and alleviates most of their disadvantages. More particularly, it reduces the danger of wind falls amongst the shelter trees to a considerable extent.

e. The Selection System.

Here the drawbacks of the group system are further intensified, without offering sufficient compensation by way of advantages in other respects. True, the danger from wind falls is reduced, and the soil is more completely protected, but this is generally accompanied by withholding from the young growth a suitable measure of light.

The system is, in Europe, confined to localities where the uninterrupted maintenance of a crop of forest trees is necessary for the protection of the soil against heavy rain, followed by denudation or erosion, avalanches, etc., in fact for so-called *protection forests* in high or steep mountains. It is also useful in forests of specially small or large extent; in the former, if the area is insufficient for a regular division into compartments, and if nevertheless a certain quantity of timber is required annually; in very large forests which are as yet in the first stage of systematic management, such as

many of the forests of India. It is also practised, generally in a rude form, where the demand for produce is as yet much below the supply.

B. Natural Regeneration from Adjoining Woods.

After the area has been clear cut, the seeding is effected by the seed falling from mother trees which do not stand on the cleared area, but alongside of it.

The points which demand attention are the conditions of success and the merits of the system.

1. Conditions of Success.

a. Sufficient Seeding of the Area.

The agencies which carry the seed on to the area are air currents, and in some cases water, or the seed may roll by its own weight down a slope. When air currents are the carrying agency, it is necessary that the seed should be sufficiently light, and that, when it falls, the wind should blow from the right direction. In this respect, the species, the force of the air current, and the relative position of the regeneration area and the mother trees are of importance. The seed of some species, as poplar, is so light that it travels for miles, while that of others falls straight to the ground. The following distances for a number of species under the influence of a moderate air current may be given:—

Birch, elm, larch .	4—8	times the height of the trees.
Spruce, Scotch pine, alder	3—4	,, ,, ,,
Maple, ash, hornbeam	2—3	,, ,, ,,
Lime, silver fir . .	1—2	,, ,, ,,

Beech and oak, scarcely beyond the reach of the crowns.

In the case of strong winds, the distances are proportionately greater; instances can be seen in Scotland where Scotch pine seed has been carried to many times the distances given above.

The distances are also greater, if the mother trees stand at a higher elevation than the regeneration area.

The direction of the wind during the fall of the seed introduces a great element of uncertainty, as it can only in rare cases be relied on.

A further complication may arise, if the seed should fall during the prevalence of a dry wind coming from one direction, while, for other reasons, regeneration should gradually proceed in the opposite direction.

b. Suitable Condition of the Germinating Bed.

This has often to be provided by working or wounding the soil. Where the roots of the trees are grubbed out the soil is sufficiently stirred, but where the stools remain in the ground special working may be necessary.

c. Protection against External Dangers.

The young crop is exposed to damage by frost, drought, and a growth of weeds. Some protection will be given by the adjoining wood, but the amount depends on the breadth of the area under regeneration at one time and the relative position of the mother trees.

d. Extent of the Clearing.

The smaller the regeneration area is, the more satisfactory will be the results. On large areas, a period of 10, 20, or more years may be required to complete the new crop which will be very uneven, and in the majority of cases artificial sowing and planting has to step in.

The chances of success are greatest, if the regeneration area has the shape of a narrow strip running along the edge of the mother trees. The breadth of such strips should not exceed the height of the mother trees, so that the area may be quickly and fully stocked, and better protection provided for the young crop against climatic dangers; the soil also keeps fresher.

Such protection is further increased, if successive clearings do not adjoin each other, but are separated by older woods. Sometimes the clearings represent patches situated in the middle of old woods. Arrangements of this kind lead, however, to a very complicated system of management; hence, they occur only where groups of trees have been thrown by wind or snow, or killed by insects. If patches are cut purposely, they often lead to the group system described above.

2. Merits of the System.

Owing to the uncertainty of the seeding and the injuries to which young tender plants are exposed, the system can be recommended only under favourable conditions of the locality, and in the case of hardy, quick growing species. Damage by insects, especially the cockchafer, *Hylesinus*, and *Hylurgus*, further narrows the limits of applicability.

SECTION II.—NATURAL REGENERATION BY SHOOTS AND SUCKERS.

It has been explained in Part I. that woody plants can reproduce themselves by means of shoots, or suckers, or both. Shoots may spring from the stool, after the tree has been cut over close to the ground, or from the stem and top if the cutting is restricted to the side branches and the upper part of the stem. Accordingly, a distinction must be made between regeneration from the root, stool, or stem. Of these, reproduction by stool shoots is by far the most important, but as in many cases it occurs in conjunction with reproduction by suckers, the two will be dealt with together.

1. Regeneration by Stool Shoots and Suckers.

As already stated, regeneration follows the cutting over of the trees. Where stool shoots are wanted, the cutting over takes place close to the ground, followed by a clump of shoots which spring, either from adventitious buds formed on the callus near the edge of the cut, or from dormant buds on the

neck of the stool. A similar mode of cutting is employed where both stool shoots and suckers are wanted. If only the latter are desired, the stump may be removed, and only the roots left. This is frequently done in the dry parts of India in the case of *Prosopis spicigera*.

The success of this system of regeneration depends on many things, of which the following require special attention.

a. Species.

Of the species growing in temperate Europe, only broad leaved trees and shrubs are adapted to the method, and even amongst these great differences exist in regenerative power.

b. Age of Wood at Time of Cutting.

Generally, reproduction is most powerful during youth up to the period of principal height growth, and under favourable circumstances for some time beyond it. The wood must be cut over for the first time at an early age. After that, the rotation depends on the required description of material (fire-wood, hop poles, bark of a certain quality, etc.), and the time up to which the stools are capable of vigorous reproduction.

The increment of coppice woods is greatest during the first few years after cutting, which may be another reason for the adoption of short rotations. On the other hand, small material and tanning bark have of late years so much sunk in price that the woods are frequently allowed to grow until they are capable of yielding timber fit for pit props or similar purposes.

c. Soundness of Stools.

Diseased stools often produce diseased shoots, though some species, as oak, are usually exempt from this liability; the same holds good in the case of suckers. It follows that diseased stools should be removed and replaced by strong plants to produce fresh and sound stools.

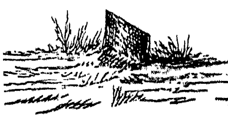
The longevity of the stools is closely connected with their

health, which is principally governed by the species and the character of the locality. A fertile soil and favourable climate increase the longevity. The stools of ash, maple, birch, and also those of beech are short-lived, lasting frequently not longer than two or three rotations; those of oak and hornbeam are almost indestructible, and between these extremes many intermediate stages exist.

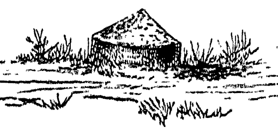
d. Manner of Cutting.

The cut produced by the removal of the stem is exposed to the effects of air, moisture, and sun, which cause a deterioration of the wood near the cut through drying up and rot, and tend to reduce the reproductive power of the stool.

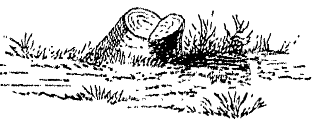
Although this process of deterioration cannot altogether be



Good.
Fig. 96.



Good.
Fig. 97.



Bad.
Fig. 98.

prevented, its extent and rapidity can be reduced by careful cutting. In the first place, the size of the cut should not be too large; in the second place, it should be smooth; and finally, it should be slanting, so that water may not rest on it (Fig. 96). In the case of large shoots, the cut may be given a slope from the centre to two sides, or it may receive the shape of a cone (Fig. 97). The cut should on no account slope inwards (Fig. 98); it should be made with a sharp billhook or axe, and not with a saw. If the latter is unavoidable, the cut should be given a smooth surface with a billhook, axe, or knife. Another important point is that the bark should not be severed from the wood around the edge of the cut.

The height from the ground, at which the tree is cut over, also influences the success. Except where inundations are feared, it is preferable to cut close to the ground, as there is

less corky bark on the root neck; besides, if the shoots appear low down, at or a little below the surface, they are more likely to develop independent roots, and thus ensure greater longevity of the stool.

In southern countries, where the sun is likely to dry up the stools, it may be necessary to cut below the ground, or to cover up the stools with earth.

e. *Season of Cutting.*

The best season of the year for cutting is a few weeks before the buds begin to swell. Various circumstances may, however, prevent this being done, such as an insufficiency of labour, the necessity for peeling the wood, etc. Where labour is not available to do the whole cutting at the most favourable period, a part must be done (in Europe) in the autumn; this has the drawback that frost during winter frequently separates the bark from the wood of the stool, or that the stools are killed outright. Again, stools which were cut over in autumn send out shoots somewhat earlier in spring, and thus render them more liable to be injured by late frosts.

Where the principal object is to obtain bark for tanning, the cutting must be done during the full flow of the sap, that is to say, in temperate Europe, in May and the beginning of June. This has the disadvantage that the new shoots do not sufficiently ripen before the early autumn frosts set in.

f. *Standards.*

The reproduction is most complete if the wood is clear cut; the more standards are left, the less favourable will be crop of shoots and suckers.

2. Reproduction by Stem Shoots, or Pollarding.

Pollarding consists in the removal of the crown of a tree, either leaving the main stem intact, or cutting it off at a certain height from the ground; in the latter case, the system is frequently called *topping*. The branches may be cut off

close to the main stem, or at a short distance from it, the latter method being preferable. New shoots spring from the cuts, and these are again cut after one, two, or more years, according to the desired size of the produce.

What has been said above regarding species, health of the trees, and manner and season of cutting, mostly holds good as regards pollarding. The system is chiefly employed in the case of willows and poplars; the former yield materials for basket work, fascines, hurdles, etc., and the latter firewood and small sticks for domestic use.

CHAPTER IV.

FORMATION OF MIXED WOODS.

The various methods of forming a wood described in the previous chapters are applicable to both pure and mixed woods. There are, however, certain peculiarities in the formation of mixed woods, which it will be necessary to indicate. As the number of possible mixtures is very large, a separate reference to each will not be attempted. It must suffice to deal with them in the following groups:—

1. Formation of even aged woods, or in which the ages of the species in mixture differ so little that they may, for practical purposes, be considered as even aged.
2. Formation of mixed woods consisting of trees of uneven age.

1. Formation of Even Aged Mixed Woods.

In Part I. of this volume (page 78), it has been explained that, in order to preserve mixtures in which the species are of the same age, their relative height growth throughout life must be specially considered. If there is a difference in this respect, any species sensitive to cover, and likely to be outgrown by associated species, must be given a start, while the latter must be capable of bearing the shade of the former. In the absence of these conditions, the species must be separated, and the utmost which can be done is to place them in alternating groups. Even then, there is no certainty that, in regenerating such a wood, the new crop will show the desired mixture. At any rate, it will be clear that the regeneration of such woods requires constant attention, lest one species should oust another.

a. Sowing and Planting in Clear Cuttings.

Sowing can be done by mixing the seed of two or more species, or by sowing one over the other, either direct or crosswise. The second method must be followed, whenever the seeds require a different covering, that which requires the deeper one being sown first. Another method is to sow in alternate strips. Such sowings are not often made nowadays, but recourse is had to planting, as it permits the mixture being arranged in any way which may be desired; the species may alternate by single plants, or by lines, or strips or groups. Again, the proportion of one species to another can be absolutely fixed. Planting in groups is specially indicated when there is a difference in the height growth, and where the conditions of the soil change from place to place, as each patch can receive the most suitable species. The size of such groups depends on circumstances; if it exceeds a certain limit, the wood can no longer be considered mixed—it becomes a series of pure woods.

Where a light demanding species is to be mixed with a shade bearer, the former can be given a start of a few years, instead of arranging the mixture by groups. In such cases, the mixture is frequently arranged by lines, the light demanding (and generally hardy) species being planted first in alternate lines, and the shade bearing species (generally tender in early youth) afterwards in the intermediate lines. In some cases, two or three lines of the former alternate with one line of the latter, or *vice versâ*.

A way of giving one species a start over another is to put in plants of different ages. Sometimes one species is raised by sowing and the other by planting, but this is rarely done nowadays, except when the former is raised with field crops. In that case, the second species is planted when the cultivation of field crops ceases.

b. Sowing and Planting under Shelter-woods.

This method is adopted in the case of species which are tender during youth, especially in respect of frost.

If an old wood exists, and a new mixed wood, consisting of a tender and a hardy species, is to be created, the former may be sown or planted alone under the shelter-wood; then, when the shelter-wood is no longer required, it is removed, and the second, hardy species planted in. This method is followed, for instance, where beech is to be mixed with Scotch pine, larch or Douglas fir.

If no old shelter-wood is available, then the hardy species is cultivated first, and when it has advanced sufficiently to provide the necessary shelter, the tender species is introduced. In this way birch, Scotch pine, and larch are planted to serve as shelter-woods (nurses) for beech, silver fir, and oak.

c. Natural Regeneration under Shelter-woods.

In regenerating a mixed wood, it is of first importance that the shelter-wood should be composed of trees of the several species in such proportion as to secure the desired mixture in the new crop. In determining that proportion, the relative reproductive power of the species must be taken into consideration, more especially the size and quantity of the seeds, the frequency of seed years, the height growth of the species in early youth, their capacity of bearing cover, their degree of hardiness, the nature of the germinating bed, etc.

Already during the last thinnings, the cuttings can be so arranged as to lead to a proper proportion of the mother trees. This process is continued, and if possible completed, during the preparatory stage. Under any circumstances, it must be completed by the seeding cutting.

In many cases, a great difficulty arises from the fact that the several species do not seed in the same year. In such cases, the seeding cutting must be made when that species seeds which is to form the bulk of the new crop, or which is the more difficult to rear; the other species, if they have not produced a sufficient proportion of seedlings beforehand, or fail to do so within a few years afterwards, must receive artificial assistance, generally by planting them.

The arrangement of the cuttings during the final stage depends on the requirements of the new crop in the several parts of the wood. Where conflicting interests present themselves, those of greater importance must prevail.

The trees to be left for the final cutting should belong to the most wind firm species, to that which is most likely to increase rapidly in size and value, and if possible to one with a thin or at any rate compact crown.

The above remarks show that it is in many cases a difficult task to guide successfully the process of regeneration in a mixed wood; hence, a method should be chosen which reduces the difficulties to a minimum. With this end in view, the several species may be brought together in groups, each of which can be treated in the manner best adapted to the particular species. If this should be found insufficient, the following method may be adopted:—

d. Natural Regeneration combined with Sowing and Planting.

Natural regeneration alone rarely leads to the desired result; only parts are successfully stocked, and sowing and planting must step in to complete the business. In applying this method, it must be remembered that generally the more favourable parts of the area become naturally stocked, leaving the inferior spots blank. If only the latter were filled up by sowing or planting the species which is deficient in the naturally regenerated patches, it would be relegated to the inferior spots, while the other species would occupy the better parts; hence, it is necessary to plant a proper number of the artificially reproduced species also into the patches already naturally regenerated.

This method is much used in Europe in the formation of mixed woods of beech with oak, ash, sycamore and other valuable timber trees. In fact, it is the best method for such mixtures. The valuable species are generally introduced by putting in strong plants; sowings are also done in the case of

shade bearing species, or where the species are arranged in separate groups.

Another instance is the regeneration of silver fir and spruce woods in the Black Forest. There, silver fir is favoured during the regeneration process, and if an insufficient number of spruce plants has sprung up, it is afterwards increased by planting.

2. Formation of Mixed Woods of Uneven Age.

It has been shown that the preservation of the mixture is difficult, when the trees are of the same age, or nearly so, and that it requires constant care and attention, lest one species should be suppressed by another and disappear. Such unremitting attention cannot always be given, apart from the expense which it involves. Endeavours have been made, therefore, to devise a method of mixing species which is less dependent on constant attention, and this has been found in giving to the mixed species a greater difference of age. Each of these requires to be regenerated at its own time, so that the process of regeneration is gone through several times in the course of one rotation, one part of the wood being regenerated on each occasion.

Many varieties of mixed woods of uneven age have been evolved, each of which corresponds, more or less, with a distinct silvicultural system. Of these the following claim attention:—

(*a.*) The group and selection systems.
(*b.*) High forests with standards.
(*c.*) Two-storied high forest.
(*d.*) Mixed coppice with standards.

a. The Group and Selection Systems.

Under the group system the regeneration of a wood extends over a period ranging up to 30 and even 50 years. By first regenerating groups consisting of the threatened species, they can be given a start up to 30 or 40 years. After these

have been regenerated, groups consisting of the threatening species are taken in hand. Taking, for instance, a mixture of light demanding and shade bearing species, such as oak, larch, or Scotch pine, with beech, silver fir or spruce, operations commence with the groups of the former, and are brought to a close by a regeneration of the latter.

Again, in a mixture of shade bearers only, such as beech, silver fir and spruce, the last mentioned is likely to outgrow the beech and also the silver fir; hence a sufficient number of groups of beech and silver fir are first established, and then the groups of spruce.

In the case of selection forests, the differences in age are still greater, and much can be done on the lines indicated above, to protect the threatened against the threatening species.

b. *High Forest with Standards.*

If such woods are mixed, the threatened species are selected for standards, if otherwise suitable for the purpose; it is essential that the rotation should not be very high, otherwise the future standards may suffer before the end of the rotation has been reached.

c. *Two-storied High Forest.*

It has been explained in Part I., page 108 that, when a high forest has run through part of the rotation, a portion of the trees are removed, and a new crop is introduced, which grows up between the trees remaining of the first crop, the two being allowed to run through an additional whole rotation of the second crop. The difference between the two crops ranges, as a rule, from 20 to 60 years. Here, then, is an excellent opportunity of protecting a threatened against a threatening species, the first crop consisting of the former, and the second of the latter. In Europe, the system is much adopted for the production of large-sized oak, larch and Scotch pine, also ash, maple and others, which at a certain age are underplanted with beech, silver fir, spruce, hornbeam, sweet chestnut, hazel

or certain exotic species, such as Douglas fir, Sitka spruce, Thuia plicata, Abies grandis, Tsuga Albertiana, and others. This underplanting had best be done in the case of larch at the age of 15 to 30 years, of Scotch pine at 30 to 40 years, and of oak at 30 to 50 years, or even later.

Fig. 99.—Larch underplanted with Abies grandis (Novar, Scotland).

d. Mixed Coppice with Standards.

This system offers, in the regeneration of the over wood, the greatest latitude for the protection of threatened species, whether in single trees or in groups. Although some of the standards may regenerate themselves naturally, the greater part are produced by planting strong plants where mature standards have been removed.

CHAPTER V.

CHOICE OF METHOD OF FORMATION.

The choice of method depends on numerous considerations. To attempt a detailed exposition of these matters in reference to the several methods would not lead to any practical result, since, after all, the choice depends on the local circumstances of each case. A few remarks regarding the main groups of methods may, however, not be out of place. These main groups are :—

(1.) Direct sowing.
(2.) Planting.
(3.) Natural regeneration by seed.
(4.) Natural regeneration by shoots and suckers.

Of these, the last-mentioned method refers almost entirely to coppice woods worked under a short rotation; it is not employed where woods are treated under a high rotation, because in rare instances only do coppice shoots reach the same size as seedling trees.

The questions which interest the silviculturist most are—

(1.) Whether to sow direct, or plant on cleared areas.
(2.) Whether to regenerate existing woods artificially, or naturally by seed.
(3.) Whether or not combinations best meet the objects of management.

These three questions, then, will be shortly discussed in the following pages.

SECTION I.—CHOICE BETWEEN DIRECT SOWING AND PLANTING.

Formerly, the artificial formation of woods was chiefly effected by direct sowing, planting being restricted to special

cases where the other method was not likely to succeed. The reasons for this were that sowing was considered to be more certain and cheaper, since it was generally the custom to use too large transplants. In the course of time, the raising of plants was elaborated, smaller plants were used, and the expense considerably reduced, so that now far more planting than direct sowing is done. Yet, it is not always a foregone conclusion that planting is better or more suitable than direct sowing, since many differing conditions and factors affect the ultimate results. The effect of some of these factors is as yet somewhat obscure, but in many respects experience has taught the forester which of the two methods is preferable under a given set of conditions. The points of view from which the choice of method may be approached are manifold, and amongst these the following deserve attention:—

(1.) Objects of management.
(2.) Desired silvicultural system.
(3.) Selected species.
(4.) Conditions of locality.
(5.) External dangers threatening the young wood.
(6.) Quality and quantity of available labour.
(7.) Cost.

1. Objects of Management.

The objects of management have been shortly indicated on pages 1 and 2, and it will readily be understood that, according to circumstances, either planting or direct sowing may more completely meet them.

Where landscape beauty is the object aimed at, few foresters would think of adopting direct sowing; where time is an object and expense of minor importance, the planting of strong transplants would be most suitable. If the object of management centres in the production of the greatest possible quantity of small material, with the least possible outlay, direct sowing would probably yield better results than planting. Again for the production of clean timber trees, sowings

with their greater density may in many cases be more suitable than planting, unless the latter be very close and thus involve a considerable outlay.

Economy in working is one of the leading requirements in silviculture. In this respect, either sowing or planting may be preferable, according to circumstances; experience, however, shows that, where plants of good quality can be raised at a reasonable outlay, planting yields higher returns than direct sowing, if time be taken into consideration.

Where the land is required for pasture or grass-cutting, planting is decidedly preferable, as cattle can be admitted at an earlier age, while grass-cutting can be commenced at once.

2. Silvicultural System.

The formation of woods to be treated under the pollarding system, and of osier beds, is best effected by planting. The same may be said of ordinary coppice woods and the production of standards in coppice. In ordinary seedling forests, any method may be adopted.

3. Species.

The species affects the choice of method in various ways. In the first place, many species produce seed abundantly only at irregular and often long intervals; hence, continuous operations can be carried on only by planting, as the production of nursery plants requires comparatively small quantities of seed, and this, if necessary, can be obtained from a distance. By keeping a quantity of reserve plants in the nursery, seedless years may be tided over without interrupting the work.

Species, the seed of which germinates with difficulty or slowly, or the seedlings of which are tender in early youth, should, in the case of clear cuttings, be propagated by planting and not by direct sowing. In such cases, it is much easier and cheaper to provide the necessary tending and protection in a compact nursery than on an extensive forest area. Under shelter-woods, direct sowing may be preferable.

Hardy species, which grow slowly during youth, should be planted; those of fast and early development may be sown direct, if this be desirable on other grounds.

The shape of the root system is also of importance. Species, which develop a compact and comparatively shallow root system, are much easier to plant than those which at once develop a deep going tap root; for the latter, direct sowing may be advisable. Long tap roots, however, may be pruned, or the seedlings raised in such a manner that they are forced to develop a compact root system; at the same time, either alternative may be of doubtful expediency; the cutting of tap roots may introduce disease due to fungi.

Mixed woods should be established by planting, as a proper mixture of the species is rarely practicable by direct sowing; at any rate some of the species must be planted. Frequently, it is desirable to give one species a start over another, and this can be done in a satisfactory manner by the use of large plants.

In the case of some species, as for instance oak, many foresters maintain that direct sowing gives more vigorous and better trees, but this depends to a large extent on the soil and climate, and also on the size of plants used; small plants give better trees than large ones. If sowing of acorns is not advisable for other reasons, the planting of one or two years old oak seedlings close together is likely to yield just as good oak trees as direct sowing.

4. Condition of Locality.

As a general rule, it may be said that planting is preferable whenever the condition of the locality is unfavourable, especially where extremes of soil and climate prevail, while in a favourable locality direct sowing may yield equally good, and in the case of some species even better, results.

Unfavourable localities are those with a wet, occasionally inundated, or very moist, heavy, cold soil; excessively loose, dry, or poor soils; those subject to be overrun by a heavy

growth of weeds, or where frost lifting may be expected. Similarly, planting is far preferable to direct sowing where extremes of climate prevail, such as in raw, frosty, exposed localities.

On steep slopes, planting is also preferable, but in very stony soil direct sowing may become a necessity.

5. External Dangers.

Seeds, as well as young seedlings, are subject to attacks by various animals, against which they can be more effectually protected in a nursery than in the forest; hence, on this account, planting is preferable to direct sowing. As regards attacks by insects, it is an open question which of the two methods is preferable. As long as only thoroughly healthy plants are used and put out with care, they may hold their own and even do better than seedlings in direct sowings; but weak plants, or those which have difficulty in establishing themselves quickly in their new home, are more subject to attacks by insects than seedlings grown *in situ*. The same often holds good as regards attacks by fungi or by rabbits.

6. Labour.

Unless direct sowings necessitate a thorough working of the soil, they require less labour than planting. Where labour is scarce, direct sowing may prove to be cheaper. Planting also requires more skilled labour than direct sowing.

7. Cost.

Whether direct sowing or planting is the cheaper method depends on the price of seed, the extent to which the soil has to be worked for direct sowings, and the cost of plants. Direct sowing is generally cheaper, but if seed is expensive and small plants can be utilised, planting may be the less costly method of the two.

SECTION II.—CHOICE BETWEEN ARTIFICIAL REGENERATION AND NATURAL REGENERATION BY SEED.

Sowing and planting can be done under the shelter of the old wood, or it can follow a clear cutting; natural regeneration can be done under a shelter-wood, or on cleared areas of moderate breadth by seed coming from an adjoining wood. The differences between the two shelter-wood methods are small, while they are considerable between the clear cutting and shelter-wood methods. The following remarks refer chiefly to the latter case.

1. MERITS OF ARTIFICIAL REGENERATION.

a. Advantages.

(1.) Artificial regeneration is independent of the local occurrence of seed years, since sufficient seed for nurseries, and frequently also for direct sowing, can be obtained from a distance. This being so, the adoption of the method enables the forester to proceed in a systematic and regular manner, doing the desired quantity of regeneration year after year, and providing the market with a steady supply or produce.

(2.) The full enjoyment of light can be secured at once to young trees which are hardy.

(3.) The trees develop more rapidly than those originating by natural regeneration, at any rate up to middle age.

b. Disadvantages.

(1.) Sowing and planting are costly. The outlay on the latter can, however, be considerably reduced by planting small plants according to a simple and cheap method.

(2.) Where artificial regeneration follows clear cutting, the young plants are exposed to damage by frost, drought, insects and weeds in a far higher degree, than if the regeneration is conducted under a shelter-wood. In fact, tender species must be raised in the latter way, so that for them clear cutting is

excluded. Insects frequently become formidable to coniferous woods raised in clear cuttings, while experience has shown them to be less dangerous to natural seedlings, especially when these are raised under a shelter-wood.

(3.) In the case of clear cuttings, the laying bare of the ground for a series of years may seriously affect the fertility of the soil, so much so that the method is hardly admissible on inferior soils.

2. Merits of Natural Regeneration by Seed.

a. Advantages.

(1.) Natural regeneration involves less expenditure than sowing or planting. In some cases, the outlay may be absolutely *nil*, but in most cases some artificial help has to be given, either by working (wounding) the soil, or by sowing and planting. Still, the outlay is considerably smaller. It must not be overlooked, however, that in the majority of cases natural regeneration requires much time; as long as the shelter trees increase sufficiently in size and quality so as to make up for any loss on this account, no harm is done, but where this is not the case, artificial regeneration may actually be more profitable, since no loss of increment occurs.

(2.) Damage by frost, drought, and weed growth is avoided, or at any rate considerably reduced. The same may be said as regards damage by insects, though perhaps not to an equal extent.

(3.) The activity of the soil is maintained, and, to a considerable extent, rendered independent of climatic influences.

(4.) Owing to the greater number of plants per unit of area, clearer and straighter stems are produced than in plantings, and also frequently in sowings, though the difference in the latter case is less decided. This advantage can be nullified to a considerable extent by dense planting and sowing, but in that case the cost is proportionately increased.

b. Disadvantages.

(1.) The method is more complicated and difficult than artificial regeneration; hence, it demands more skilful foresters.

(2.) The intermittent nature of seed years produces many drawbacks as regards the equalisation of the yield and the control of operations.

(3.) The removal of produce is also more expensive.

3. Summing Up.

Neither the artificial nor the natural method of regeneration is the best at all times and under all circumstances; only a consideration of the local conditions can lead to a sound decision as to which is preferable in a given case.

SECTION III.—COMBINATION OF SEVERAL METHODS OF FORMATION.

In the preceding pages various artificial and natural methods of forming a wood have been described. Each of these methods has special advantages under certain conditions. As the latter may, and frequently do, vary within a narrow extent of area, it follows that two or even more methods may be employed in the formation of a wood, thus securing greater success and frequently a reduction of expenditure. As a matter of fact, in practical silviculture such combinations are the rule and not the exception.

Of the combinations here indicated the following are of special interest:—

1. Combination of Artificial Formation and Natural Regeneration by Seed.

Natural regeneration assists artificial formation only in rare cases, but the reverse constantly happens. Natural regenerations by seed rarely are so complete that they do not require artificial help, which can be afforded by sowing or planting, generally the latter. There are always certain parts of the

regeneration area which, for one reason or another, do not become stocked and have to be planted up. Then, it frequently happens that the ruling species shall be mixed with others which must be brought in artificially; or one of the species in a mixed wood fails to produce seed for a considerable period, while the other, having regenerated itself, demands the removal of the mother trees; here again artificial help is required.

In many cases, it can be foreseen that certain portions of an area are unfit for natural regeneration; these may at once be artificially stocked, even before the natural regeneration of the remainder has commenced. In other cases, a part of the area may have been deprived of the necessary shelter trees by natural phenomena; here artificial shelter-woods may have to be planted.

From the above remarks it will be seen that artificial and natural formation may be started at the same time, or the one may precede the other. In all such cases, blanks in existing woods should be filled up with strong plants of a quick growing species.

2. Combination of Artificial Formation with Regeneration by Stool Shoots or Suckers.

This combination occurs constantly in coppice woods, where stools, which have died or become diseased, are replaced artificially by putting in strong plants or slips, and in some cases by sowing seed, such as acorns or chestnuts. Only in rare cases are such stools replaced by natural seedlings.

3. Combination of Natural Regeneration by Seed with Regeneration by Stool Shoots and Suckers.

This case may occur in high forest, where the seedling trees have been injured by frost, game, cattle, mice, hail, etc.; it may then be advisable to cut them back in order to get strong healthy shoots.

The combination occurs further in coppice with standards.

Here it is desirable that the standards should be seedling trees, and their regeneration may be effected by the seed falling naturally on the ground.

4. Combination of Artificial Formation with Natural Regeneration by Seed and by Shoots.

It occurs in coppice with standards, when a sufficient number of the latter cannot be obtained by natural regeneration. In the majority of cases, a considerable amount of planting must be done, so as to obtain a suitable number of standards, and to replace stools which no longer produce vigorous shoots.

PART III.

TENDING OF WOODS.

TENDING OF WOODS.

When a wood has been established, it will, if left undisturbed by outside influences, grow on and reach maturity ; the individual trees will, however, enter upon a lively struggle for existence, and the ultimate results, in the majority of cases, will meet only to a limited extent the objects for which the wood has been established. Moreover, external injurious effects will make themselves felt, and further reduce the returns. In order to realise those objects more fully, especially where a certain class of timber is desired, the growing wood requires well-directed tending from its formation up to the time when it is finally cut over. Care must be taken that the most favourable conditions for growth are secured, and that the development of the individual trees is so guided as to produce the desired results ; in other words, the forester must take measures to preserve the continued activity of the locality, and to see that the wood has throughout its life a suitable composition. Of the several parts into which silviculture has been divided, that which deals with "Tending of Woods" is by far the most important. To sow or plant a wood is a comparatively simple matter; natural regeneration is more difficult, but the ultimate success of forestry depends on the careful tending of the growing woods at every stage of their life. The want of a proper appreciation of this fact has led to the unsatisfactory condition in which so many woods in Britain are found.

The subject divides itself naturally into the following two sections :—

(1.) Preservation of the factors of the soil.

(2.) Tending the crop of growing wood.

The effects of the locality upon forest vegetation, and *vice*

versâ, have been dealt with in Part I. of this volume, while the protection of the soil and growing wood against injurious influences are dealt with in Vol. IV. on Forest Protection. In this place, only the important points will be shortly indicated, with special reference to the silvicultural aspect of the subject.

In order that a crop may be fully productive, it is necessary to establish, and then to preserve, those physical and chemical conditions of the soil on which a healthy and vigorous growth depends. The means adopted in agriculture for this purpose are working the soil and manuring. Both are expensive, and in silviculture they are only feasible in cases where the increased returns at least cover the outlay; they are, therefore, either out of the question, or can be employed only to a very limited extent, and the forester must endeavour to accomplish what is needful by other means. Fortunately, timber trees are far less exacting than field crops, so that the more modest means at the disposal of the forester suffice for their healthy development.

It has been shown on page 36 that the productive power of the soil in silviculture depends on:—

(1.) A sufficient depth.
(2.) A suitable degree of porosity.
(3.) „ „ „ moisture.
(4.) „ chemical composition.

In silviculture, these conditions can be maintained or procured to a sufficient extent by the following simple agencies:—

(*a.*) The preservation of a suitable cover overhead.
(*b.*) The preservation of the natural covering of the soil, more especially of humus.

How these affect the soil has been described on page 43. The principal fact is that the activity of the soil and a vigorous development of the crop growing on it are intimately connected with each other, and that the one exercises a healthful

effect upon the other. At the same time, their requirements are sometimes opposed to each other, and in such cases it must be a leading principle that the tending of the crop should always aim at a proper preservation of the fertility of the soil.

The above remarks refer to the case of woods which are fully stocked. Cases may, however, occur where it is desirable to interrupt the leaf canopy at a certain age, so as to form open woods; in such cases, separate steps must be taken to preserve the fertility of the soil.

Again, during the first part of the life of a wood it is subject to special dangers, most of which disappear later on, when the attention of the forester must be directed to other matters,

The subject may, therefore, be divided into the following three chapters:—

Chapter I.—TENDING OF WOODS DURING EARLY YOUTH.
,, II.—TENDING OF FULLY STOCKED WOODS AFTER EARLY YOUTH.
,, III.—TENDING OF OPEN WOODS FOR THE PRODUCTION OF LARGE TIMBER.

CHAPTER I.

TENDING OF WOODS DURING EARLY YOUTH.

Young woods require special protection against external dangers until they can shift for themselves; they must be kept clean, and a proper density or composition of the crop preserved. Accordingly, the subject will be divided into four paragraphs.

1. Protection against External Dangers.

The details of this subject will be found under Forest Protection. For the present purpose the following notes will suffice :—

a. Game.

Deer, rabbits, and hares must either be kept down, or the areas must be fenced. Various other measures have been recommended to protect each plant against damage by the application of substances noxious to these animals, such as of tar, glue, fluid lime, and evil smelling preparations. Most of these are not only expensive, but also liable to injure the plants. With lime good results have been obtained, and the further development of the plant is not seriously interfered with. On the whole, however, fencing is in the long run the cheapest and most effective. Squirrels frequently do serious damage by peeling trees and by biting off the leading shoots of young trees; they must be kept down by shooting. Black game often does much damage to young plants, but it is difficult to prevent this, except by keeping the game down.

Foxes should be carefully preserved, as they are most useful animals in forestry.

b. Fire.

Although woods require protection against fire at all periods of their life, it is specially necessary during early youth. Protection is afforded by removing all inflammable matter, or clearing fire traces around the area and at suitable intervals in the interior.

In addition, the area must be watched, so that any fires which occur may be promptly extinguished.

c. Frost and Drought.

Where regeneration takes place, whether naturally or artificially, under a shelter-wood, the latter provides the necessary protection against frost and drought, or, at any rate, insures a considerable reduction of the danger in either case. In cultivating cleared areas, shelter for tender species must be artificially provided by growing simultaneously, or better beforehand, a special shelter-wood, or nurses. The trees selected for this purpose must be frost-hardy, and possess a thin or moderately dense crown. The best nurses in temperate Europe are birch, larch, and Scotch pine. Where danger from late frost is excessive, larch, owing to its early sprouting, is less well adapted as a nurse, but it does very well in all other localities. In moist localities, alder and willows have been similarly used.

The nurses may be distributed evenly over the area, or placed in alternate lines. They are removed when the tender species can do without them. Frequently, some of the nurses are retained so as to form a mixed wood.

d. Cold Winds.

The effects of raw, cold winds are often more disastrous than frost produced locally by radiation. Where they are to be feared, lateral as well as vertical shelter is required. This may be given, either by adjoining woods of sufficient height and density, or, in their absence, by artificial shelter belts or wind breaks. These must be dense, and they should be

established some time before the area to be protected is placed under cultivation or regeneration. The species, of which wind breaks consist, should if possible be evergreen, and with dense crowns coming close to the ground. Favourite species are Austrian, Corsican, and Cembran pine, and spruce.

An alternative measure consists in mixing a hardy species, such as Scotch or Corsican pine, with a tender crop. Or the wood is treated under the selection system, when trees of all ages are intermixed on the same area. In that case, the middle aged and younger trees provide lateral shelter for the young growth, while the old trees give vertical shelter.

In all these cases it is essential that the edges of the wood, towards the side whence cold winds blow, should always be kept as dense as possible. It is best to place the plants in the shelter belts according to the triangular system.

What has been said above applies not only to frost, but also to drought, more especially in tropical climates, where hot, dry winds may be even more disastrous than cold winds are in higher latitudes.

e. Weeds.

In the case of the shelter-wood systems, under regular and successful management, noxious weeds are kept sufficiently in check to enable the young tree growth to make its way up through them. If this is not the case, and in the cultivation of cleared areas, such weeds must be removed wherever they threaten to choke the young plants, until the latter have reached a sufficient height to hold their own. Heather, broom, brambles, climbing plants, birch, sallow, etc., may become even more dangerous than ordinary grasses and weeds.

In considering the degree to which noxious plants require to be cleared away, it must be remembered that in moderation they may act beneficially by sheltering the very young trees; hence, interference is not called for until they actually become noxious. The clearing of weeds involves in many cases a

heavy expenditure. While it is a mistake to do too little by allowing the young crop to be overgrown, unnecessary expenditure may be incurred by doing too much. All outlay on young woods has a serious bearing on the financial results by the time the wood is harvested; hence, it should be kept as low as is compatible with efficiency. The important point is that the leading shoots of young trees should not be interfered with. This done, it is doubtful whether additional cleaning will repay the expenses connected with it.

f. Insects and Fungi.

These form standing dangers to woods throughout life, especially where coniferous trees are grown over extensive areas. The measures which should be adopted to protect forests against them are taught in Forest Protection. Several species of both insects and fungi are specially dangerous to young forest plants. It is the duty of the forester to watch carefully his regeneration areas, and to destroy all injurious insects as soon as they appear, so as to prevent the spreading of the evil. In such cases, prompt action is essential. In many instances it is necessary to let areas lie fallow for a few years, until insects, which breed in the stools and the refuse of the old wood, have disappeared again. As an illustration, *Hylobius abietis*, the pine weevil, may be mentioned, which frequently becomes disastrous to young Scotch pine and spruce woods. In the case of attacks by fungi, the diseased plants should be removed and destroyed as speedily as possible.

2. Preservation of a Proper Density of the Crop.

In the majority of cases, it occurs that, for one reason or another, some of the plants fail, thus causing smaller or greater blanks. All these must be filled up without loss of time. As long as the young crop is only a few years old, recruiting, or beating up, can be done with plants of the same kind as the original crop. Such plants may be obtained from nurseries, or, in the case of natural regeneration, they may be taken from places where the plants stand too close together.

Direct sowing is also done, but planting with strong plants is preferable, because these have a better chance of keeping pace with the rest of the crop.

If the original crop is already so far advanced that plants of the same species are not likely to catch it up, the recruiting must be done with a quicker growing species; if this is not feasible, with a shade bearing species likely to stand the shade of the surrounding saplings. Unless beating up is done at once, it becomes very expensive and uncertain in its results.

Sometimes a young crop of a valuable species may be too thin throughout the area, so that the soil is exposed, and the young trees are not sufficiently forced up. In such cases it may be useful to interplant the whole area with a quick growing species, such as birch, Scotch pine, or larch, which remains until the first species has grown sufficiently to form by itself a complete leaf canopy. Frequently, a portion of the filling species is retained as a permanent constituent of the crop.

Young woods, which are the result of direct sowing or of natural regeneration, are frequently, here and there, too densely stocked. If no action were taken, the young trees would grow up too weedy and lanky; hence, some of them must be removed. If they are not to be used for planting elsewhere, they may be cut off close to the ground with a knife, sickle, billhook, or shears. If the plants have already reached some size, the removal of a portion must be done gradually, else the remaining plants may be bent over from being deprived of the support of their neighbours.

3. Cleaning of Young Woods.

The cleaning of a young wood has for its object to remove in good time all growth which interferes with the proper development of the principal species. Such interfering growth may consist of stool shoots amongst a sufficient number of seedling trees; mis-shapen or spreading young trees; trees which have accidentally established themselves by seed blown on to the area (as poplars, willows, and birch), or

carried there by animals, as sweet chestnuts, acorns, hazelnuts, and others. Often spruce, Scotch pine, lime, alder, and elm also appear where their cultivation was not intended.

It would, however, be a mistake to remove all such additions without distinction. Frequently, they are very welcome in filling up otherwise thin woods; hence, they should be removed only where they interfere with the principal species.

Mis-shapen, spreading trees, which are not likely to develop into useful timber trees, should be unmercifully removed as early as possible, as they will interfere with the development of more promising neighbours. The same may be said of diseased trees.

It is often desirable to make several cleanings, especially where the undesirable growth forms a considerable portion of the crop, and where its removal at one time would leave blanks. In some cases, it may be judicious to accept a portion of the accidental growth as a constituent of the final crop, in others it may serve as a shelter-wood.

At this stage some pruning may be done. Where double leaders have been produced, one must be removed. Side branches of young trees may be shortened, especially those low down.

4. Preservation of a Proper Mixture.

This difficult subject must receive special attention while a wood is young; much can be done to secure a proper mixture during the operations of recruiting and cleaning which have just been described, by planting into blanks those species which are otherwise deficient in number, or by removing an excess in other places.

Again, where one species is threatened by another, the latter can be checked either by lopping off its side branches, by topping, ringing, or removing some of the trees.

The operation demands the forester's special attention, since it is much easier to produce a proper mixture at this early period of life than later on.

CHAPTER II.

TENDING OF FULLY STOCKED WOODS AFTER EARLY YOUTH.

WHEN the trees, which compose a wood, have become sufficiently large to close up and form a complete leaf canopy, several sources of injury disappear. Weed growth has ceased to affect the trees, and dangers from frost and drought have been reduced to a minimum. Danger from fire is not so acute as during the early period of life, and in a temperate climate it may disappear altogether, especially in the case of broad leaved species. On the other hand, danger from insects and fungi continues, while strong winds, snow and rime may break or throw down trees; such damage may extend over considerable areas.

While the forester may thus be relieved of some cares peculiar to young woods, he must henceforth tend them in other and very important directions. He must more particularly give to each tree that growing space which is best suited to its further development, without sacrificing the full activity of the soil; he must also take measures to insure a high technical utility to the material under production.

The principal silvicultural measures, by which justice is done to the above-mentioned requirements, may be arranged under the following three headings:—

I. Removal of dead, injured, or otherwise undesirable trees.
II. Pruning.
III. Thinning.

SECTION I.- REMOVAL OF DEAD, INJURED OR OTHERWISE UNDESIRABLE TREES.

In every wood, trees sicken, die, or are injured from a great variety of causes. Amongst these may be mentioned

an unfavourable soil, frost, drought, fire, hail, lightning, injuries to the crown, stem, or roots, attacks by insects or parasitic fungi. Again, the crowns and stems of trees may be broken by strong winds, snow and rime, or single trees and whole groups may be thrown down. From one or the other of these causes, there will always be found a certain quantity of material, which, if not removed as speedily as possible, will stimulate the increase of injurious insects and of fungi. The latter have of late years been recognised as the cause of considerable damage to woods, since modern botanists have explained many important phenomena formerly imperfectly understood as to their origin. In this respect, attention is invited to the ravages of *Fomes annosus* and *Armillarea mellea* in Scotch pine and spruce woods; of *Trametes Pini*, and *Peridermium Pini*, the pine blister, in Scotch pine woods; *Dasyscypha calycina*, the larch canker fungus; *Melampsorella Caryophyllacearum*, the silver fir canker fungus, the various species of *Polyporus* on broad leaved and coniferous trees, etc.

Far greater, however, than the danger from fungi is that from insects. Many species of the latter are apt to become disastrous to whole woods, extending over large areas. Most of these find suitable conditions for multiplying in the presence of dead and dying trees, refuse wood, stumps, etc. Hence, it is advisable that all such material should be removed as speedily as possible.

Where regular thinnings, presently to be prescribed, are carried out, all dead and dying trees are removed at the same time. Such thinnings occur only at certain intervals, and as it would be detrimental in many cases to leave the dead material in the forest until the next thinning comes round, it is frequently necessary to make special cuttings for the purpose of removing it; these are called "*dry wood cuttings*" or "*cleaning cuttings*." In carrying these out, all valuable material should be used or sold, and the refuse burned under supervision. If danger from insects be imminent, it may be necessary to remove the stumps of trees as well, or at any

rate to bark them and the principal roots, or cover them with earth.

SECTION II.—PRUNING.

1. Objects of Pruning.

Where the object of management centres in the production of valuable timber, in other words of trees with long clean boles, it is necessary for them to lose their side branches up to a certain height from the ground. Trees which grow up in crowded woods lose their lower branches naturally, owing to the insufficiency of light, and this process proceeds up the stem with the elevation of the leaf canopy from the ground. A great difference exists, however, in this respect between the various species of forest trees. Broadly speaking, it may be said that the rapidity, with which trees lose their lower branches in crowded woods, is inversely proportional to their power to bear shade. Hence, light demanding trees will lose their lower branches quicker than shade bearers. In some cases, the dead branches drop quickly to the ground, and in others they remain for years producing knots and irregularity in the timber laid on in the meantime. Trees grown in the open retain their lower branches more or less throughout life, and they produce in consequence timber of inferior value, as compared with trees grown in fully stocked woods.

In the cases where the lower branches do not drop off naturally, they may be removed artificially, and this process is termed "Pruning." In silviculture, the principal objects of pruning are as follows:—

(1.) Increase in the value of the pruned tree.

(2.) Freeing younger growth from the too great cover caused by overhanging trees.

(3.) To stimulate the expansion of the crown in the upper part of the tree.

Branchless boles are of greater value than those with branches, because the timber splits better, and the scantlings sawn out of them have fewer knots. In order to realise

these advantages, pruning may be extended to the removal of dead branches, or to that of green ones as well. Pruning may exercise an additional advantage in causing the bole to grow more cylindrical, instead of approaching the shape of a cone; in other words, it may make boles less *tapering*.

The second of the above-mentioned cases occurs where a wood consists of two or more generations of different ages, as in coppice with standards, the selection system, two-storied high forest, etc. It may also occur in young woods, where a slow growing valuable species is threatened by a faster growing one. In such a case, it may be preferable to prune the latter instead of removing it altogether.

Trees with many side branches, which have been subjected to unfavourable conditions of growth, frequently show signs of failing strength in the upper part of the crown. By removing the lower branches, the vigour in the upper part may be restored. This case applies specially to oak standards, the boles of which, exposed to light after a prolonged crowded position, have developed epicormic branches.

2. Dangers connected with Pruning.

The removal of dry branches or remnants of branches is not, as a rule, conducive to any danger to the life or health of the tree, provided the operation be carried out in a careful way. On the contrary, it often reduces the danger from rot, because it facilitates the process of occlusion, or covering over of the wound by new layers of wood.

Matters are different in the case of green branches. Here, the wound caused by the removal of the branch frequently causes rot, because the unprotected open wound offers a fit germinating bed for the spores of fungi; the wound, on drying, opens out in rents and cracks, into which rain water may carry the spores; the latter germinate and cause decomposition, which spreads and reduces the value of the stem, or may entirely destroy it. Several dangerous parasitic species of fungi thus enter trees.

It is essential, therefore, that the wound should be closed as quickly as possible and made impermeable to the spores of fungi and to water. This is effected by nature through the process of occlusion, provided the wound does not exceed a certain size. The time required for this operation depends on the size of the wound, the vigour of the tree, the manner in which the wound is made, and above all on the species.

Pruning green branches is least dangerous and objectionable in the case of oak and most conifers which are in vigorous health, provided the operation is carefully done and the wound does not exceed 3 inches in diameter. Oak closes the wound rapidly by occlusion, while wounds on conifers exude turpentine, which protects them to a considerable extent.

As regards other European species, the evidence is at present conflicting. Pruning green branches of poplars, birch and willows is undesirable, because their wood is liable to rot quickly. According to Hess, some of the important species may be arranged in the following descending series in respect of the activity of occlusion :—*Broad leaved species :* Oak, beech, hornbeam, lime, ash, maple, birch. *Conifers :* Larch, silver fir, Scotch pine, spruce. In the case of the last-mentioned species and of birch, the pruning away of green branches is, in the opinion of most foresters, altogether undesirable.

Under any circumstances, the pruning of green branches should not be undertaken without due consideration of the advantages which are likely to be realised and the disadvantages connected with the operation ; this is of special importance in all cases where the objects of management centre in the production of large sized timber, which can only be obtained by permitting the trees to grow and increase for many years after the pruning has been carried out. If it has been decided to prune, the operation may be restricted to the stems which are likely to form the final crop, and perhaps those which will be taken out at the final thinning. Nor should the pruning be done all at once to the full height

which it is proposed to clear of side branches; it is much better to do it by two or more instalments, as the higher branches become either dry, or at any rate somewhat inactive. In the case of silver fir in the Black Forest, treated under the selection system, pruning, when done at all, rarely extends over a greater length than 15 feet at a time, the operation moving higher up the stem at certain intervals with the advancing height growth.

3. Execution of Pruning.

Where the object is to produce valuable timber trees, the branches should in all cases be cut off close to the main stem, but without injuring the bark of the latter; only in this way can quick occlusion of the wound be expected. If the object be merely to relieve young growth of cover overhead, the above rule may be neglected.

The work may be done with the knife, hatchet, billhook, shears, or saw. Cutting instruments produce a smoother surface of the wound, but, unless very carefully handled, injuries to the bark of the main stem are likely to occur. The saw produces a less smooth surface, but, if carefully handled, it does no injury beyond the actual cut. Heavy branches should first be cut off a short distance from the stem, and then, by a second cut, the remaining stump removed, to ensure the production of an even cut and to avoid tearing the bark of the main stem.

Saws are used, either in connection with a light ladder, or they are placed on poles. In the first case, pruning can be carried out to a considerable height. Saws placed on poles are effective only up to a moderate height, 12 to 18 feet.

Of hatchets, that constructed by Courval (Fig. 100) is recommended. Fig. 101 represents a pushing chisel, with which branches can be removed up to a moderate height. Fig. 102 is a bow-less saw, and Fig. 103 an ordinary hand saw, Fig. 104 is a saw in the shape of a bayonet fastened on a pole, designed by the author; it cuts with the downward stroke.

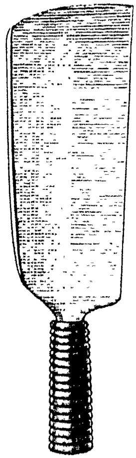


Fig. 100.

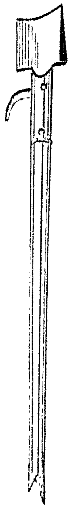


Fig. 101.

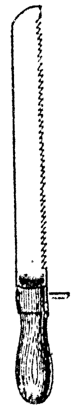


Fig. 102.

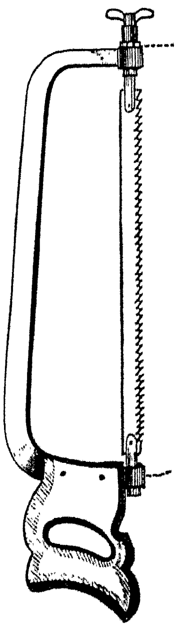


Fig. 103.

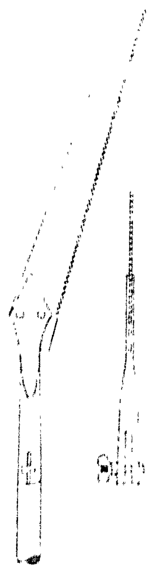


Fig. 104.

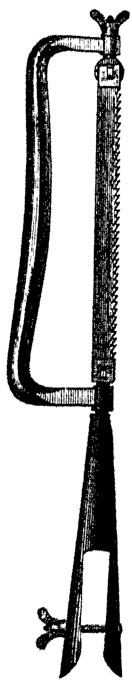


Fig. 105.

Fig. 105 represents Ahler's pruning saw, which is also fastened to a pole. The two last mentioned are specially recommended, where the use of a ladder is not preferred.

Wounds, which are so large that they are not likely to be speedily closed by occlusion, must receive a waterproof covering; this is necessary even in pruning large branches of coniferous trees.

The most suitable covering consists of a layer of coal tar, made sufficiently fluid by an addition of oil of turpentine, and laid on with a brush. The artificial covering will only stick on when the sap is down; hence, in temperate Europe the best time for pruning is autumn and the first half of winter. Dry branches and snags may be cut off at any time of the year, provided the living tissue of the tree is not injured during the operation.

According to R. Hartig, pruning green branches while the tree is in sap causes a somewhat rapid decomposition of the wood near the wound. For this reason also, pruning in the first half of winter is recommended.

SECTION III.—THINNING.

1. General.

One of the most important objects in the formation of a wood is to stock the area sufficiently, so that a complete cover overhead may be established as early as possible. This is desirable, not only for the preservation of the soil, but also for a proper development of the trees. In order to ensure early closing overhead, it is necessary to bring on to the ground a much larger number of plants than can find room on it for any prolonged period. Soon after a complete leaf canopy has been established, the trees commence pressing one against the other, there is not enough growing space for all, and a *struggle for existence* sets in. A portion of the trees outgrow the rest, and they rear their heads up to the full enjoyment of the light. Between and below them are the rest of the trees; some of these still enjoy with their leading shoots light

from above, though they are already surrounded by higher trees; others have already been left behind to such an extent that they are actually deprived of the direct enjoyment of light, in other words they are suppressed; they live on for a shorter or longer period according to species and other circumstances, and then die.

Thus there are four principal classes of trees, namely:—

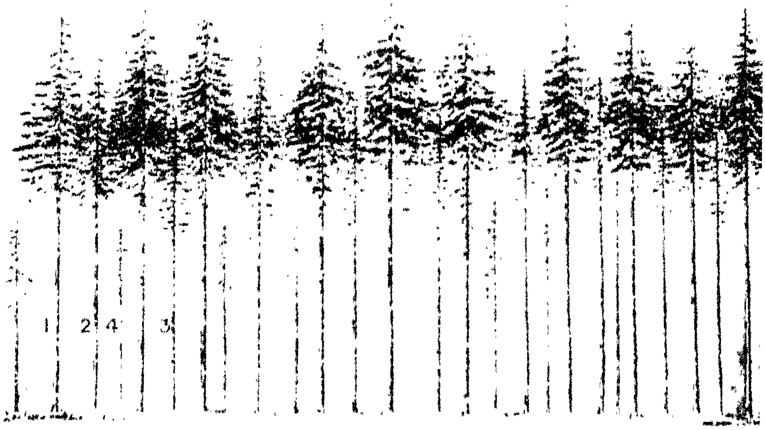


Fig. 106.—Diagram to illustrate the Theory of Thinning.
1. Dominating trees. 2. Dominated trees.
3. Suppressed trees. 4. Dead trees.

(1.) Dominating trees, in full enjoyment of light from above.
(2.) Dominated trees, hemmed in by the former.
(3.) Suppressed trees, alive but over shadowed.
(4.) Dead and dying trees.

This struggle, if not interfered with, continues whilst height growth lasts, and it gradually reduces the growing space of each dominating tree to such an extent that they cannot develop in the most advantageous manner; consequently, such trees are likely to assume a thin, lanky shape, so that they are frequently unable to stand upright, if deprived of the support of their immediate neighbours. They are liable to be

bent and broken by wind, snow, or rime. To obviate this, the forester interferes in good time by removing a portion of the trees; he *thins* the wood. Thinnings, then, are cuttings which have for their object to provide for each tree left standing, and especially to those which are to remain until the end of the rotation, that growing space which is best suited for its further development, according to the objects of management. It is necessary to explain this somewhat in detail.

2. The most suitable Growing Space.

As the objects of management differ, so must the most suitable growing space. Apart from this, that space differs according to the age of the wood, the species, the soil, elevation, and aspect of the locality.

a. Objects of Management.

A tree growing in a free position, in complete enjoyment of vertical and lateral light, will develop a full crown and root system, and lay on a maximum of volume. This is no doubt a great point, but it is counterbalanced by serious drawbacks:—

In the first place, a wood grown in this fashion does by no means always produce the greatest volume per acre, as the total production is represented by the average volume per tree multiplied by the number of trees per acre. Although each tree in a crowded wood has a smaller volume than one grown isolated, yet, owing to the greater number of trees per acre, a crowded wood may have, and generally has, a greater total volume per acre than one in which the trees grow isolated. Secondly, isolated trees are liable to suffer in height growth and in straightness. In the third place, such trees are generally covered with branches low down, and in consequence they produce less valuable timber. In the case of conifers, the timber is also liable to be of an inferior quality, owing to the greater breadth of the concentric rings. Last, but not least, open woods cannot preserve the fertility of the locality; hence, they are only admissible on fertile localities, or special

measures must be taken to preserve the fertility of the soil.

These considerations govern the most profitable growing space in any particular case. It is conceivable that under certain conditions the correct policy is to remove all dead, suppressed, and dominated trees, and even a portion of the dominating trees, while in others the dominated and even suppressed trees may have to be carefully husbanded, so as to realise the objects of management in the highest possible degree.

Age of Wood, in years.	Number of Trees, per acre.	Mean Growing Space per Tree, in square feet.	Decrease in the Number of Trees during 20 Years.	Increase of Growing Space per Tree, in per Cent.
I. *Scotch Pine:*				
20	1,420	30	... 700 ...	... 100
40	720	60	... 350 ...	... 97
60	370	118	... 140 ...	... 60
80	230	189	... 60 ...	... 35
100	170	256		
II. *Spruce:*				
20	2,970	15	... 1,840 ...	... 160
40	1,130	39	... 620 ...	... 118
60	510	85	... 200 ..	... 66
80	310	141	... 90 ...	... 40
100	220	198		
III. *Beech:*				
20	2,550	17	... 1,610 ...	... 171
40	940	46	... 517 ...	... 124
60	423	103	... 174 ...	... 70
80	249	175	... 83 ...	... 60
100	166	262		
IV. *Oak:*				
20	1,920	23	... 1,400 ...	... 270
40	510	85	... 274 ...	... 118
60	236	185	... 79 ...	... 50
80	157	277	... 43 ...	... 38
100	114	382		

b. *Age of Wood.*

As the number of trees per acre decreases gradually from several thousands to a comparatively small number at maturity, it follows that the growing space increases with advancing age, though not evenly. Statistics collected on this point gave the results shown in the above table for pure woods of Scotch pine, spruce, beech and oak grown on soils of first quality.

These data show that:

(1.) The increased requirement of space is very great between the ages of 20 and 60 years; it then falls gradually up to the age of 100 years.

(2.) Many trees must be removed during the earlier part of a wood's life, and comparatively few later on, always assuming that the area is to remain fully stocked.

c. *Species.*

Light demanding species require more space than shade bearers; broad-leaved species more than conifers.

The above table shows that the light demanding Scotch pine requires considerably more growing space than the shade bearing spruce; the latter less than the broad-leaved beech, although it stands less shade.

Comparing the growing space of Scotch pine, larch, oak, and birch with that of spruce, beech, and silver fir, the proportion is about 100 to 65.

d. *Soil.*

Until some time past middle age, the number of trees is larger on poor than on rich soil; afterwards the difference disappears. The reason is that the struggle for existence commences earlier and is more energetic on good than on poor soil. In this respect, considerable differences exist between the various species.

e. Altitude.

Under otherwise equal conditions, the number of trees per acre increases with altitude, at any rate up to a certain elevation. The statistics of the Black Forest for the three regions approximately indicated as below 1,200, 1,200—2,400, and 2,400—3,600 feet showed the following proportion in the number of trees all of the same age :—100, 126, 244. This law could not be established above 3,600 feet, because at that height regular woods disappear. It was further noticed that the difference is more pronounced in the case of shade bearing species and during the earlier part of life, than in the case of light demanding species and later on in life.

f. Aspect and Slope.

Aspect in itself causes only slight differences in the growing space. Southern and western aspects, in the case of beech in the Black Forest, had up to 5 per cent. more trees than northern and eastern aspects. Sloping ground has generally the same number of trees as level ground, other conditions being equal.

g. Summary.

It may be said that the average growing space per tree is, apart from age, greater in the case of light demanding species, on good soil, and in low elevation, than under the reverse conditions.

In judging of the desirability and the degree of thinning in any particular wood, the forester must take into consideration—

(1.) The objects of management.
(2.) The density of the crop.
(3.) The age of the crop.
(4.) The species.
(5.) The character of the locality, its soil, climate, and the special external influences to which it is exposed.

3. The Theory of Thinning.

Whatever the objects of management may be, the theory of thinning may be summarised in the answers to the following three questions :—

(1.) At what age of a wood should thinnings commence?
(2.) To what trees should they extend—in other words, how heavy should the cuttings be?
(3.) After what intervals should they be repeated?

Definite answers to these questions can be given only on the basis of accurate comparative statistics. The collection of such data is now in active progress in Europe, but some time must necessarily elapse before final conclusions can be drawn from them; in the meantime, the following observations seem justified.

It has been explained above that, during the struggle for existence, four different classes of trees are produced, namely, dominating, dominated, suppressed, and dead trees, and the question arises in how far each of these should be interfered with at each thinning. It is obvious that the dead trees must be removed at every thinning, as they cannot influence the other three classes, while their presence in the wood is a constant source of danger from insects and fungi, and in some cases from fire. Whether, and to what extent, the suppressed trees, the dominated, and dominating trees should be removed depends, apart from species, chiefly on the character of the locality and the objects of management. On fertile soils, an interruption of the cover overhead is of comparatively small importance, but on inferior and even middling soils this should be avoided. In the latter cases, the dominated and even suppressed trees, or at any rate a portion of them, must be retained, whenever the dominating trees alone are not sufficiently numerous to provide a complete leaf canopy. If, on the other hand, the number of dominating trees is so large that they interfere with each other's proper development, a portion of them may also be removed.

As regards the objects of management, it suffices in practical silviculture to distinguish between the following two cases :—

(*a*.) Production of the greatest quantity of material.

(*b*.) „ „ highest quality „

In some cases, the two objects may be realised by an identical treatment; in others, the one demands a method of thinning different from that which is desirable in the other.

a. Production of the greatest Quantity of Material.

Experience has shown that the greatest quantity is produced in the shortest possible time by a vigorous development of the dominating trees; so that the suppressed and dominated trees are only retained so long as they are required for the protection of the soil.

i. *Commencement of Thinnings.*—The first thinning should be made as soon as the struggle for existence has commenced, that is to say, when there is no longer sufficient space for the proper development of all trees. Such early thinnings are to the interest of the dominating trees, which thus are enabled to lay on an extra quantity of wood, and to acquire a greater power of resistance against snow, rime, and wind. In practice, they are sometimes delayed, because their execution involves expenditure which may not be covered by the receipts from the sale of the thinned-out material. The financial loss thus incurred, however, may be more apparent than real, as it is generally more than covered by the favourable development of the remaining trees.

ii. *Degree of Thinning.*—A thinning is called—

"Light," when only dry and suppressed trees are removed;

"Moderate," when, in addition, the whole or part of the dominated trees is removed;

"Heavy," when also a part of the dominating trees is cut; in this case the suppressed trees may be left to give shelter to the soil.

In the present case, where quantity is the object, the thinnings should on the whole be heavy, subject to the special requirements of the species and the preservation of a sufficient leaf canopy. As the demands on the growing space are very great during the first half of life, thinnings must then be comparatively heavier than later on; heavier in the case of light demanding and quick growing than in that of shade bearing and slow growing species; heavier on good than on poor soil.

Much depends on the original density of the wood; hence, direct sowings and woods resulting from natural regeneration require, as a rule, heavier thinning than plantings.

iii. *Repetition of Thinnings.*—Thinnings should be repeated, whenever they become necessary. The more energetic the growth, the quicker should the thinnings follow each other; hence, the intervals will be comparatively short during the first half of life, and they become longer with advancing age. For the rest, the length of the intervals depends on the species and the quality of the soil.

A frequent repetition of the thinning should not be replaced by thinning too heavily at any particular time; such a measure would not secure the most favourable development of the dominating trees.

In summing up, it may be said that, where the object is to produce quantity, the thinnings should commence early, be heavy, and frequently repeated during the first half of the life of a wood, and be more moderate and repeated at longer intervals during the second half.

b. Production of High-class Timber.

Where the production of high-class timber is aimed at, quantity must to some extent be sacrificed. Trees fit to yield such timber must answer the following description:—

(1.) The boles must be tall, straight, free of branches, and as little tapering as possible.

(2.) Differences in the breadth of the concentric rings must be slight.

(3.) The timber must have a high degree of density.

Boles free from branches and non-tapering are not produced, if heavy thinnings are made at an early age of the wood; at any rate not in the same degree as if the wood were kept dense, when the lower branches are more rapidly killed for want of light. Pruning cannot make up for this, though it can do something.

There is naturally a tendency to produce broader rings during youth than later on; heavy thinning at an early age increases the difference, leading to the formation of trunks which consist of a number of broad rings in the centre part, surrounded by a series of narrow rings. Such timber is for many purposes of smaller value than if the rings are of uniform breadth throughout.

As regards the density of the timber, a distinction must be made between the various species. In the case of those broad leaved species which have the pores in the spring portion of the wood, broad rings indicate high density, and narrow rings comparatively low density; here, heavy thinnings are indicated. The same probably holds good for species which have the pores uniformly distributed over the ring. In conifers, however, the matter is reversed, as in their case broad rings usually represent low density and narrow rings high density; consequently, heavy thinnings must be avoided, at any rate up to a certain age.

On the whole, it may be said that, in the production of high-class timber, heavy thinnings at an early age should be avoided. The rule here, according to which the thinnings are to be made, runs as follows:—

The wood should be thinned lightly until towards the end of the principal height growth. Then the thinnings should gradually become heavier, so as to assist a selected number of the best trees by the gradual removal of the others. In this way, the breadth of the annual rings will be fairly even

throughout life, although the increment of the individual tree is increased. The method leads, towards the end of the rotation, to a moderate interruption of the cover which accelerates the decomposition of an accumulation of humus and brings the soil into the best possible condition for natural regeneration, when that is the object aimed at.

Many and varied are the methods of thinnings which have been recommended. Some of these restrict the thinnings to the suppressed and dominated trees, while others prescribe the removal of a considerable portion of the dominating trees. The former are called "*éclaircie par le bas*" in French and "*Niederdurchforstung*" in German. The latter are called "*éclaircie par le haut*" in French and "*Hochdurchforstung*" in German; the thinning is then done more in the dominating and dominated trees than in those which have been left behind in the struggle for existence and no longer compete; the latter, if capable of living on, may be left to assist in the protection of the soil, or to act as wind brakes. Whether much good is done by leaving such trees is doubtful. Their crowns are generally some distance from the ground, and they may carry on only a feeble existence, so that their effect on the soil is very limited. Extensive experiments are being made on the continent of Europe to determine the advantages and disadvantages of the several systems of thinning, and in the meantime the rule given above is that which the author recommends as likely to lead to the best results.

4. Thinning of Mixed Woods.

In the foregoing pages the theory of thinning as applicable to pure woods has been given. Generally, the points aimed at are to stimulate production and to develop the most suitable individuals for the final crop. In mixed woods, a third consideration presents itself in the preservation of a suitable mixture without interfering with the maintenance of a sufficient leaf canopy; this leads to deviations from the theory as indicated above.

In the case of mixed woods, it may often be necessary to remove a dominating tree of one species, because it threatens to suppress a tree of another species which must be preserved for the sake of the mixture. To guard against an interruption of the cover in such cases, the dominated and even suppressed trees must be more carefully husbanded than in pure woods, until, with the advancing age of the wood, the mixture has been secured. Frequent and light thinnings are in such cases indicated. Their actual degree depends much on the light requirements of the more valuable species in mixture. The operation is facilitated, if the several species are mixed by groups instead of by alternating single trees.

Where a valuable timber species is mixed with a less valuable one, the former must be favoured from an early age, so as to bring it to the highest possible development, if necessary at the expense of the less valuable species. As long as the valuable species is of quicker growth than the other, the operation is comparatively simple; but if it is of slower growth, all individuals of the secondary species, which threaten to over-top it, must be cut away, until the principal species is secure.

5. Thinning of Coppice Woods.

These thinnings are conducted according to the same principles as in high forest, whenever the number of shoots is so great that there is not enough growing space for all. More especially in oak coppice, the quality and quantity of bark may be considerably influenced by leaving on each stool only the two or three best shoots and removing the others. Such thinnings are generally made in the second half of the rotation. In coppice with standards, such thinnings are frequently required to set free seedling plants growing amongst the coppice.

6. Principal Advantages of Thinnings.

The principal advantages of thinnings are as follows:—

(*a.*) Thinnings give the means of guiding the development of a wood in accordance with the objects of management,

either by producing the greatest possible quantity, or the best possible quality of produce; in some cases, both these objects may be combined.

(*b.*) They afford the means of preserving a suitable mixture in the case of mixed woods.

(*c.*) Danger from insects, fungi, and fire is greatly reduced by the prompt removal of dead and sick trees.

(*d.*) They afford the means of strengthening the trees destined for the final crop against damage by snow, rime, and wind.

(*e.*) They yield substantial early returns.

The returns from thinnings should not be under-estimated, especially where the object of management centres in the production of quantity. Even when the management centres in the production of first-class timber, the following relation between the thinnings and final returns exists on soils of the first quality and under a rotation of 100 years in each case :—

Species.	Returns in solid cubic feet per acre.			Proportion of Thinnings to Final Returns in per cent.
	Thinnings.	Final Return.	Total.	
Silver fir	4,710	15,650	20,360	30
Spruce	4,450	14,890	19,340	30
Scotch pine... ...	3,370	8,130	11,500	40
Beech	3,520	8,910	12,430	40
Oak	2,680	8,300	10,980	32

The value of thinnings is further increased, when their financial aspect is considered, as early returns have a decided influence upon the rate of interest yielded by forestry, provided they do not seriously affect the final return.

7. Execution of Thinnings.

The advantages of thinnings can be fully realised only if the operations are conducted in a careful and judicious manner; in other words, they must be attended to by a competent forester, and not left to the wood-cutters.

In young woods, which have as yet a large number of trees

per acre, thinnings should generally be carried out in the presence of a competent forester; only where the wood is absolutely uniform throughout, a sample may be prepared as a guidance for the woodmen, and this only if the latter are thoroughly reliable and competent. In the more advanced stages of life, each tree to be removed should be marked separately and in the forester's presence, and this is best done while the trees are in leaf, so that the effect of the removal may be properly judged. Special care is necessary where valuable timber trees are to be produced, where dominating trees are to be removed, and where a proper mixture of species is to be preserved. A good plan is to mark the trees destined for the final crop, and to remove the others when the most favourable development of the former requires it.

The exposed edges of a wood should be thinned heavily from an early age onward, so that the remaining trees may retain their lower branches, and thus be trained to withstand strong winds. If the wood be subject to the effects of raw, cold, dry, or hot winds, the exposed edge should be kept as dense as possible, and an additional strip, some distance from it, may be kept in a similar condition.

The best time for the execution of thinnings is winter, but local circumstances demand deviations from this rule. In high mountains, they must be done in summer, as the localities are generally inaccessible during winter.

CHAPTER III.

TENDING OF OPEN WOODS FOR THE PRODUCTION OF LARGE TIMBER.

1. The Theory.

In the foregoing chapter it has been shown how thinnings should be conducted, if the principal part of a wood—the dominating trees—are to be given increased space and enjoyment of light, followed by increased increment, without, however, interrupting the leaf canopy to such an extent as to affect injuriously the continued activity of the soil. Under this method of treatment, the one aim acts antagonistically to the other, and it is by no means easy to conciliate the two interests. Hence, the problem presents itself, whether the better portion of the dominating trees cannot be more completely isolated, while the soil is protected by other means. There are other considerations which press the subject upon the attention of the forester. Under the ordinary system, as described above, the production of large sized timber demands a high rotation, and any measures which tend to reduce the latter must be welcome. Experience has shown that by isolating the trees, timber of a certain size can be produced in little more than half the time required under the method of continuously fully stocked woods.

Another point is that many, and more especially the light demanding, species have a natural tendency to open out, or to form large crowns.

It is of additional importance that under a system of heavy thinnings considerably larger intermediate yields are obtained early in the rotation. This, in conjunction with the more rapid development of the trees constituting the final crop, leads to more favourable financial results.

On the other hand, the early isolation of a portion of the trees has weighty drawbacks. In the case of many species, it may injuriously affect the height growth of the trees. Then, isolated trees maintain their side branches low down, and even develop fresh ones, which for many purposes seriously reduce the value of the stems. In the case of conifers, the quality of timber also may be lower, owing to the formation of exceptionally broad concentric rings. Isolated trees are further liable to form more tapering boles than those grown in fully stocked woods. In the majority of cases, a sufficient layer of humus cannot be preserved, its place being taken by weeds. Moreover, a suitable degree of moisture cannot be maintained. It follows that, except on really fertile soils, other means must be devised to preserve the continued activity of the soil. This is done by the introduction of an underwood, or soil protection wood. But even then it is found that the extra diameter increment, laid on after isolating the trees, will hold out only on soils of some quality, while on indifferent soils it will, after a few years, sink back to its previous amount.

The general theory of the method of treatment in the case under consideration may shortly be described as follows :—

Commencing with the first thinnings the most promising trees are singled out, and these are isolated sufficiently by increasingly heavy thinnings, so as to permit the introduction of an underwood. As soon as the latter has established itself, and is capable of protecting the soil, a further heavy thinning is made, by which the remaining trees are completely isolated. Subsequently, more thinnings follow, as required by the extension of the crowns of the overwood.

The underwood can be established in a variety of ways, such as by sowing or planting, by natural seeding, or by coppicing a portion of the overwood. In some cases, the underwood itself is allowed to grow into timber trees (two-storied high forest); in others, it remains a soil protection wood, and is periodically coppiced.

The procedure differs considerably according to species and the objects of management. To meet the special requirements of each case, a considerable number of modifications have been elaborated. Some of these commence with the isolation in early youth, while others during the greater part of the rotation follow the system described in the last chapter, and reserve to its latter part the isolation of the more valuable trees.

Although the treatment has been recommended for almost all species, it is easy to perceive that thinly crowned species, which are generally light demanding, are better adapted for the method than those with a dense crown, as the underwood has a better chance of thriving under the former, and doing justice to the task which it is called upon to perform. In Britain, the oak, larch, and Scotch pine have, in a rough way, been treated according to this method for a long time past. On the Continent, the treatment has been elaborated in comparatively recent times.

2. Principal Forms of Treatment.

a. Isolation of a few Selected Trees, without Underwood.

A limited number of selected trees are placed in a free position by removing all surrounding trees which threaten to interfere with them, the rest of the crop being kept in a fully stocked condition. The system should be applied only in case the main part of the wood consists of a species with full crowns, and where the selected trees are of quicker height growth than the rest, or have been given a start.

To avoid loss of height growth and the retention of low side branches, the operation should not be commenced until towards the end of the period of principal height growth.

The treatment is adapted to mixed woods of beech and light demanding broad leaved species, such as oak, ash, and elm.

b. Prolongation of the Regeneration Period under the Shelter-wood Systems.

Woods treated under artificial or natural regeneration under a shelter-wood offer excellent opportunities for the realisation of the extra increment due to an isolated position of a limited number of trees. In the same degree as the shelter-wood is thinned out by successive cuttings, the remaining trees profit by accelerated increment; the process can be further extended by retaining a limited number of trees for an extra term of years, or by prolonging the regeneration period.

The method is adapted to thin crowned, wind firm trees. Shallow rooted trees are likely to be thrown by wind. The injurious effect of trees with crowns coming low down upon the young growth must be mitigated by pruning away their lower branches.

c. Retention of Standards in High Forest.

A limited number of the most suitable trees are, after the wood has been regenerated, retained as standards for part or the whole of the second rotation, and in some cases even for a third rotation. Only wind firm species are thoroughly suited for such treatment, and, moreover, they should be thin crowned. The number of standards depends on the density of their crown and the quality of the soil; only perfectly healthy, well-formed trees should be chosen, especially those which have cleared themselves of branches to some height, to obviate the necessity of pruning. The tending of the proposed standards may usefully be commenced some time before the end of the first rotation, as indicated under *a*.

d. Isolation of Trees in Conjunction with an Underwood.

A wood is uniformly thinned, and an underwood introduced by sowing, planting, natural seedings, or by coppicing a portion of the overwood. Thoroughly satisfactory results are obtained only, if the overwood consists of thin crowned and the underwood of shade bearing species. In temperate Europe, oak,

ash, elm, larch, and Scotch pine are the species specially suited for the overwood, and beech, hornbeam, silver fir, spruce, and in some cases Douglas fir, Weymouth pine, sweet chestnut, ash, and hazel for the underwood. Sometimes the underwood is itself allowed to grow up into trees, when the system is called "two storied high forest"; in other cases, when consisting of broad leaved species, it is treated only as a soil protection wood, and is periodically coppiced. Beech makes the best underwood, as it bears much shade and improves the soil more than any other species. Silver fir comes near it. Hornbeam is best in frost localities. Spruce should be used only in fresh localities, as on dry soil it may cause the overwood to fall off in growth. Of late years, various exotic trees have been used for under planting, such as *Abies grandis*, Lawson's cypress, *Thuia plicata*, *Tsuga Albertiana*, Sitka spruce, and others.

Where the underwood is permitted to attain the size of timber trees, it is cut with the overwood; the latter may, however, be retained for two rotations of the underwood, thus producing specially large timber.

A few remarks on the tending of the more important species will further illustrate the method.

i. Oak as Overwood.

A fully stocked oak wood is, when the proper time has arrived, thinned rather heavily at frequent intervals, say every 5 to 10 years, according to the locality; during these operations, all trees with a tendency to lag behind are removed as well as ill-shapen and diseased trees. At the age of 30 to 60 years, according to circumstances, a specially heavy thinning is made and the underwood started, beech being best for the purpose. When the underwood has established itself, say 10 to 15 years afterwards, another heavy thinning is made, by which the remaining trees are isolated. Subsequently more thinnings follow, at moderate intervals, in the same degree, as the oaks develop and threaten to close up again.

It is estimated that in this way about 50 oak trees per acre can be made to reach a diameter in 120 years, which in a fully stocked wood they would reach in about 200 years.

ii. Larch as Overwood.

This being a quicker growing and shorter lived tree than oak, the first specially heavy thinning and underplanting may be done between the 15th and 30th year. The underwood should consist of beech. Silver fir is also recommended, but it grows slowly during the early part of its life. Other species suitable for underplanting may be found in the Douglas fir, Weymouth pine, and the other exotics mentioned above.

In this manner, 75 to 100 larch trees per acre may be brought to large timber size in 60 to 80 years.

iii. Scotch Pine as Overwood.

The heavy thinning and underplanting may take place between the 20th and 40th year. Beech is an excellent underwood, but spruce is also admissible in this case. Douglas fir and Weymouth pine may do, where the locality is suitable. The last-mentioned species grow so rapidly that they will reach timber size at the same time as the Scotch pine.

iv. Other Species as Overwood.

Ash, elm, and sweet chestnut may be treated in a manner similar to that indicated for oak, but the underwood is introduced at an earlier age. Various other species, such as spruce, silver fir, and beech, either pure or mixed, have been tried and recommended for treatment under this method, but the author does not consider it worth while to enter into a discussion of the question, under what conditions and in how far they are suited for the purpose.

3. Execution of the Work.

The selection of the trees for removal must be most carefully considered, as mistakes made in this respect are difficult

to rectify. The main point is that, almost from the first thinning, the trees likely to form the final crop are favoured and trained for their ultimate purpose. They should consist of the best trees which are likely to develop into fine, valuable timber trees of large size; to enable this favoured portion of the wood to reach such proportions in the shortest possible time, much of the rest of the wood must be sacrificed. This should not be done, unless the sacrifice is more than covered by the special excellence of the final crop, a case which can be expected to occur only on fairly favourable localities, which insure an extra increment of the isolated trees during a considerable period of time, without favouring an objectionable development of side branches.

PART IV.

SILVICULTURAL NOTES ON BRITISH FOREST TREES.

SILVICULTURAL NOTES ON BRITISH FOREST TREES.

The theory and practice of silviculture, as described in this work, have been illustrated by instances taken from the more important forest trees grown in temperate Europe. For the sake of reference, it will be found useful to bring these scattered remarks and other information together in a set of notes on each of the trees which are of real silvicultural importance in Great Britain and Ireland.

The trees naturally arrange themselves into two groups, the broad leaved and coniferous species. Of each group, the important shade bearers have been placed first, as the notes on the light demanders depended on those referring to the former. Generally, the notes have been made as short as possible; if a full account of each tree had been given, this part would have attained the size of a book. Apart from the author's own experience, the following works have been utilized:—

Hess: "Die Eigenschaften und das forstliche Verhalten der wichtigeren Holzarten."

Elwes and Henry: "The Trees of Great Britain and Ireland."

Mayr: "Fremdländische Wald und Park Bäume für Europa."

The following explanations will be useful:—

(1.) The average specific gravity of air-dried wood has been taken from Hess.

(2.) By volume increment is here understood the mean annual production per acre in fully stocked woods, calculated from the increment of the most favourable rotation.

(3.) The information about insects refers principally to Britain.

(4.) The details regarding Insects and Fungi will be found in Volume IV.

BEECH—*Fagus sylvatica* (L.).

a. Utility.

Beech yields excellent firewood and very good charcoal. The timber is not of much value where strength and durability are wanted; it is brittle and short grained. Specific gravity, air dried, on an average, ·74. Under water it lasts well. Formerly the timber was much used in machinery, especially by millwrights; nowadays iron has replaced it for many purposes. Beech wood is still used for construction in the interior of houses, for furniture, in carpentry, turnery, etc., more especially for the manufacture of chairs in Buckinghamshire and adjoining counties. By polishing, the wood can be made to assume the colour of mahogany. On the Continent it is much used for packing cases, barrels, wooden shoes (sabots), and heels of ladies' boots. It is used also for railway sleepers, after treatment with antiseptics. The leaves are used for litter, the nuts as fodder for pigs and deer; the seeds yield a superior oil. The wood is rich in potash.

b. Distribution.

It is found in temperate Europe from Norway to the Mediterranean, or between the 40th and 60th degree of latitude, also in Western Asia; it is apparently indigenous in England, and found planted in Scotland and Ireland. It is a tree of the lower mountains and plains; going up to about 700 feet in Norway, 1,200 feet in Derbyshire, 4,500 feet in the Alps, and 7,000 feet on Mount Etna.

c. Locality.

Climate.—Beech is fairly hardy as regards winter frost, but very sensitive to late spring frosts, which, during early youth, frequently injure or even kill it. It also suffers from drought. It stands more shade than any other indigenous broad leaved species. It requires a fair amount of moisture in the air;

hence, it grows well in the vicinity of the sea and on northern and eastern aspects, while it disappears in the eastern part of Europe owing to the drier continental climate. It is liable to be thrown by strong winds, but not to any excessive extent.

Soil.—Beech requires a soil which is at least of middling depth, of a moderate degree of porosity, fresh and fertile; it thrives best on loamy soils, and especially on marls and on calcareous soils generally; also on sandy soils, provided they are thoroughly fresh and contain water at a moderate depth in the subsoil. Wet soils are unsuited, and inundations fatal to beech.

d. Shape and Development.

The stem of the beech divides, as a rule, only in the upper part; the crown remains oval until towards the end of the principal height growth, when it becomes flat or rounded off at the top. Owing to its shade bearing power, the crown extends far down the stem, if grown in the open. In fully stocked woods, the crown occupies about the upper third of the height of the tree.

The root system extends to a moderate depth, the tap-root being of no importance after the first 5 or 6 years. Beech is of slow height growth during the first years of life, compared with other broad leaved species; when from 20 to 30 years old, the rate of height growth increases, so that it outgrows the other broad leaved indigenous species, as a rule also the oak, reaching an ultimate height of about 110 feet, and under specially favourable conditions considerably more. In Normandy, trees up to 150 feet high have been measured.

Spruce, silver fir, larch, Weymouth pine, and Douglas fir attain, under ordinary conditions, a greater height than beech, though the silver fir grows slower during early youth.

The volume increment of beech is greater than that of the other indigenous broad leaved species, but smaller than that of the principal conifers. According to the latest yield tables,

the total production of timber and firewood under a rotation of 100 years should be the following :—

Quality of Locality.	Mean annual production per acre in cubic feet.		
	Timber and Fuel.	Timber only, down to 3 inches diameter on small end.	Timber according to quarter girth measurement.
I., or best	152	124	93
II., or middling ...	93	74	55
III., or lowest ...	47	32	24
Average	97	77	57

If grown in crowded woods, beech as a rule does not reach an age of much more than 200 years; in the open, it attains a much greater age.

e. Reproductive Power.

Beech commences producing full crops of good seed at the age of about 60 years, if grown under favourable conditions; it yields heavy crops, but full masts cannot be counted on at shorter intervals than 5 years, and often 10 to 15 years; they are very plentiful; partial masts occur during the intervals. Taking both factors together, the reproduction of beech by seed is less favourable than that of most other indigenous species.

Reproduction from the stool is feeble, as compared with most other broad leaved species; it ceases after the age of 40 years, and the stools rarely produce vigorous shoots after three or four rotations; it is best on marls.

f. Character and Composition of Woods.

Beech is eminently adapted for growing in pure woods, since it shades the soil thoroughly up to an advanced age, maintains, and even improves, its fertility, and bears much shade. For the same reasons, it is equally well adapted to form the principal constituent of mixed woods. Probably no other species equals it in this respect. Trees like oak, ash,

maple, elm, silver fir, Scotch pine, larch, and also spruce, thrive best when mixed with beech; in fact, this is the case with almost any species which thrive on localities suitable for beech, a subject dealt with under each species.

g. Silvicultural Systems.

Beech is specially adapted for high forest. It is less well suited for coppice woods, owing to its comparatively feeble reproductive power from the stool. It appears as underwood in coppice with standards. In high forest, the rotation should range between 80 and 140 years, in coppice between 20 and 35 years.

In high forest, it is grown in even aged and uneven aged woods; large areas are treated as selection woods (Buckinghamshire). The systems best adapted for beech are the shelter-wood systems, especially the uniform and group systems. It is the best species for underplanting open woods of valuable timber trees.

h. Formation of Woods.

Beech is specially adapted for natural regeneration by seed under shelter-woods, if the cuttings are arranged in a suitable manner. Direct sowing and planting can also be done, but the young crop must be sheltered, whenever late frosts and drought are apprehended.

The seed ripens in October, and falls shortly afterwards, retaining its germinating power for about six months. Up to 80 per cent. have been found to germinate, but it is considered good seed if 65 per cent. germinate. One pound of seed contains, on an average, about 2,000 nuts.

Direct sowings may be made in autumn or spring; in the former case, the seeds are liable to attacks by animals, and the seedlings, owing to their early sprouting, to damage by spring frosts; in the latter case, the nuts must be kept in an airy place or shed, and turned over periodically (during dry weather towards spring they may be slightly sprinkled with water to prevent drying up). If sown in spring, the nuts

sprout after four to six weeks. About 150 pounds of nuts per acre are required for broad-cast sowings and proportionally less for partial sowings. The nuts receive a covering of three-quarters of an inch on soil of middling density, somewhat more on loose and a little less on heavy soil.

In nurseries, the seed is generally sown in drills. The seedlings may be left in the seed bed for one or two years, when they are pricked out in lines, the latter being about 12 inches apart, and the plants in the lines from 4 to 8 inches. When the plants have stood two years in the lines, being then altogether either three or four years old, they are ready for putting out into the forest. They are usually planted in pits from 3 to 4 feet apart. Where well-shaped trees are aimed at, the planting distance should not be more than 3 feet. For underplanting, two years old seedlings are frequently used. As a general rule, the seedlings and young plants require protection in the nursery against frost, as well as against hot sun.

It is not desirable to prune beech plants.

The process of natural regeneration under a shelter-wood is, on the whole, slow; it is essential that the soil should be brought into the proper condition for the germination of the seed, as described on pages 236 7. If this has not been done, the soil must be worked, when a seed year arrives; this is best done by light hoeing; the seeding cutting is comparatively light, and the cuttings in the final stage are regulated by the character of the locality and the requirements of the young crop. Under favourable circumstances, the whole regeneration period may be completed in 10 years, but frequently it extends to 20 years and even more.

i. Tending.

Fertility of the Soil.—Fully stocked beech woods preserve, and even improve, the fertility of the soil to a greater extent than any other species, owing to their dense foliage up to an advanced age, and the heavy fall of leaves.

External Dangers.—Late frosts are the greatest enemy of

beech; during early youth they kill or seriously damage the plants, and even later on the tender parts of the tree are liable to suffer; hence, it must be raised under shelter, which is provided either by the old crop, or by a special shelter-wood of hardy species, such as Scotch pine, birch, and larch. In natural regenerations, the edges of the shelter-wood must be kept dense, to afford protection against cold winds. In the cultivation of blanks, an artificial shelter-wood must be grown some years beforehand.

Beech suffers also from drought while young. Later on, it is, more than any other species, exposed to blistering of the bark by the sun; the bark is also separated from the wood if struck by the morning sun after a heavy night frost; hence, it is not well suited for standards, apart from the heavy cover which the tree gives.

Storms, snow, and rime are only to a limited extent hurtful in beech woods after early youth. Snow falls occurring in spring may, however, bend and break the young trees.

Cattle and game like to browse beech; red deer, hares, rabbits, and mice peel the bark. Insects, apart from the following species, rarely do much damage. The leaves are devoured by lepidopterous larvæ, especially those of *Bombyx pudibunda*, and *Halias prasinana*, and sometimes the polyphagous *Liparis monacha*, as well as by the weevil *Orchestes fagi*. An aphis, *Cryptococcus fagi*, kills old trees; this pest has much increased of late years. The freshly cut timber is liable to the attacks of *Tomicidæ*, and other boring beetles. In nurseries, the May cockchafer may do considerable damage by gnawing the roots of the plants.

Of fungi, *Phytophthora fagi* destroys young seedlings; where it appears in large quantities, seedlings cannot be raised for 5 to 8 years; hence, nurseries must be changed, or used for other species. *Nectria ditissima* causes canker on the stem, which may, however, also be the consequence of frost. The so-called green rot is due to *Peziza æruginosa*.

Pruning.—Beech stands prunning better than some other

species, but it is rarely, if ever, done, unless the shade injures other more valuable timber trees.

Thinnings are commenced at the age of 25 to 40 years, according to locality; they should at first be moderate, afterwards heavy, where fine timber is wanted. For the production of firewood only, they may be heavy beginning at an early age.

HORNBEAM—*Carpinus Betulus* (L.).

a. Utility.

The hard and heavy wood is an excellent fuel, and it yields good charcoal. The timber is very tough, and is used in machinery by the millwright, for wheels, and a variety of other purposes. Specific gravity of air-dried wood, ·75. The ashes are rich in potash. The leaves yield good fodder.

b. Distribution.

It is found in temperate Europe up to the 57th degree of latitude in West Russia. Indigenous in the south of England; planted in Scotland and Ireland. Goes up to 1,200 feet in the Harz Mountains, and to about 3,000 feet in the Alps; generally a tree of the low lands and low hills, but in the Caucasus it is said to go up to 5,600 feet.

c. Locality.

Climate.—The hornbeam requires only a moderate temperature, and thrives even in cold moist localities unsuited for beech. It is one of the most frost hardy species, but rather tender as regards summer heat. It stands a considerable amount of shade, but not as much as beech. It seems to require a moderately moist atmosphere, and prefers north and east aspects. It is to some extent liable to be thrown by wind, but resists snow and rime rather well.

Soil.—Hornbeam likes a soil which is somewhat loose, of at least middling depth, thoroughly fresh if not moist, and minerally rich. As regards moisture, it stands between beech

and ash, and in respect of mineral matter in the soil it is not quite so exacting as beech. Loams, sandy soils rich in humus, and marls suit it best; here it attains its full development. At the same time it is found on dry soils, though of inferior development, and on heavy clay soils; it frequently replaces beech in heavy soils and in frost localities.

d. *Shape and Development.*

The stem of the hornbeam is generally divided into branches comparatively low down. The shape of the tree, if grown in a favourable locality, approaches that of the beech; on inferior soils it sinks down to an insignificant tree, with a short bole and large crown. The root system is not deep going; there are strong side roots which reach a moderate depth.

It grows somewhat quicker than beech during the first years of life, but it rarely reaches a total height of more than 75 feet.

Its volume increment is considerably smaller than that of beech; nor is hornbeam as long lived as the beech.

e. *Reproductive Power.*

Hornbeam commences bearing full crops of seed when about 40 years old, and it seeds plentifully almost every year, at any rate every other year, so that its power of production by seed is on the whole great.

The reproduction from the stool is excellent; the shoots appear at any part which has been coppiced. The stools last for hundreds of years; the tree is eminently suited for pollarding.

f. *Character and Composition of Woods.*

Hornbeam appears in pure woods in Eastern Europe, and also in England (Epping Forest). It is not equal to beech in its capacity for improving the fertility of the soil, since it has a lighter foliage, does not maintain a cover overhead so long, and does not bear so much shade; the leaves also decompose

more rapidly than those of beech. At the same time, it stands next to beech in this respect amongst broad leaved species, and may replace it in localities unsuited for beech.

Hornbeam appears chiefly in mixture with beech and oak, but also, like the beech, with other species, but not to the same extent.

g. Silvicultural Systems.

Hornbeam can be grown as high forest, coppice, or pollards. It appears as underwood in coppice with standards, and makes an excellent soil protection wood in open woods of valuable timber trees. It also makes excellent hedges.

As high forest, it would generally be treated under a rotation not exceeding 100 years, as coppice from 15 to 35 years, and as pollards from 5 to 10 years.

h. Formation of Woods.

Hornbeam can be sown, planted, or naturally regenerated; the latter is a suitable method. Sowings and plantings do not require shelter.

The seed ripens in October, and falls from that time until towards spring; it keeps its germinating power for two or three years; up to 80 per cent. are capable of germinating; it is good seed, if 65 per cent. germinate. One pound contains on an average about 15,000 clean seeds without wings.

The seed, if sown in spring, germinates only in the second spring, that is to say, about eighteen months after ripening; if sown fresh in autumn it somtimes germinates in the following spring. The best treatment consists in bedding it mixed with sand in a ditch, stirring it from time to time, and sowing it in the spring of the second year. About 35 pounds of seed per acre are required for broadcast sowings; it requires a covering of about ½ to ¾ of an inch.

In nurseries, the seed should be sown in drills; the seedlings may be pricked out when one year old. Plantings are done with plants three years old and upwards, the plants

being put about 4 feet apart. They stand pruning well. The tree can also be propagated by cuttings, which may be several feet long; the latter method may be employed for hedges. In regenerating hornbeam naturally by seed, the seeding cutting is much heavier than for beech, while the remaining shelter-wood may be removed much more rapidly, owing to the hardy nature of the tree.

i. Tending.

Hornbeam is well adapted to maintain the fertility of the soil, but not to the same extent as beech. It is little threatened by external dangers; the tree is frost hardy, but during youth liable to suffer from continued drought. Inundations affect it little. Game and cattle browse the leaves, and mice peel the bark, which is also sometimes done by red deer. The damage heals, however, quickly.

The hornbeam rarely suffers from insect attacks. The species infesting it are much the same as those of the beech. In addition, the larvæ of the Winter moth, *Geometra brumata*, strip the hornbeam of its young leaves.

Fungi:—Exoascus carpini produces witches' broom; canker on stems and branches is produced either by *Nectria ditissima*, or by frost.

On the whole, hornbeam woods require little tending. The tree stands any amount of pruning. The thinnings are done on lines similar to those referring to beech during the first half of life; afterwards hornbeam thins out naturally more rapidly than beech.

OAK—*Quercus* (Tournef.).

The two species of oak which will be dealt with, are the English or pedunculate oak = *Quercus pedunculata*, Ehrb., and the sessile-flowered oak = *Quercus sessiliflora*, Salisb. From a silvicultural point of view, they are so much alike that they may be taken together, any differences being specially noted.

a. Utility.

Oak timber is the most valuable of the indigenous species; it is heavy, hard, very durable, and splits well; it makes a good fuel. It is used for many purposes, in shipbuilding, housebuilding, implements, machinery, manufacture of casks (as split wood), railway sleepers, in fact for any purpose where a strong durable timber is required. The bark yields an excellent tanning material. The acorns are good fodder for pigs and deer, and are also used for tanning and dyeing. Specific gravity of air-dried wood: Pedunculate oak, ·76, sessile-flowered oak, ·74.

b. Distribution.

Pedunculate Oak.—All over Europe up to the 60th degree of latitude, in North Africa, and eastwards to Syria. It is a tree of the low lands, but goes up to 1,500 feet elevation in England, to 3,000 feet in the Alps, and to 4,500 feet in Greece. It is indigenous in England, Ireland, and in Scotland up to Sutherland; it ascends to 1,350 feet in the Highlands.

Sessile Oak.—Does not go quite as far north as the pedunculate oak, but rises higher in the hills, up to 4,000 feet in the Alps, and to more than 6,000 feet on Mount Etna. Somewhat more a tree of the low hills than the pedunculate oak, but becomes a tree of the low lands in the northern part of Europe.

The pedunculate oak is more frequent in Britain than the sessile oak, but the latter is common in Wales.

c. Locality.

Climate.—Oak requires warm air; it suffers from late frosts, but not so much as beech, as it sprouts later in spring; it also suffers from severe winter frosts. It is a light demanding species, which should have its head free to the full enjoyment of light. It does not require much moisture in the air. It is more storm-firm than any other indigenous species.

The sessile oak requires somewhat less warmth in the air than the pedunculate species; hence it goes higher in mountains.

Soil.—Oak requires a soil which is deep, at least fresh, warm, and fertile; it accommodates itself to moist soil, and is not very sensitive as regards inundations. Fertile loamy soils cause its highest development, but it is also found on clay, and on sandy soil if it is sufficiently moist. On the whole it is one of the most exacting indigenous species. It thrives better on southern than on northern aspects.

The sessile oak is somewhat less exacting as regards fertility, and requires a little less moisture in the soil; hence, it is found on poorer and drier soils than the pedunculate oak. If grown as coppice, the oak is less exacting than if grown as a timber tree.

d. Shape and Development.

The stem of the oak has a decided tendency to divide into strong branches comparatively low down, forming a large spreading crown, which becomes flat or rounded off with advancing age. The branches are gnarled and knee-bent. The root system is deep going with a strong tap-root. Its height growth during youth is moderately fast, somewhat faster than that of beech, which before middle age catches it up. Whether beech or oak may ultimately reach the greatest height depends on the locality. Generally, oak does not reach a total height of more than 110 feet. Under specially favourable conditions, as in Normandy, it grows up to 150 feet high. It attains a great age, even up to 1,000 years. Oak reaches a large diameter. The volume increment is as follows under a rotation of 100 years:—

Quality of Locality.	Mean annual production per acre in cubic feet.		
	Timber and Fuel.	Timber only down to 8 inches diameter on small end.	Timber according to quarter girth measurement.
I., or best	127	110	82
II., or middling ...	94	77	58
III., or lowest ...	62	45	34
Average	94	74	58

These data refer to pedunculate oak grown on low lands; the production of sessile oak is slightly smaller. The production of oak on localities of the first quality is smaller than that of beech; it is larger on the III. quality, because the minimum quality of locality, on which oak is grown, is higher than that used for beech.

The shape of the sessile oak differs somewhat from that of the pedunculate species; its branches tend more upwards, and are less gnarled and knee bent. Its height growth is slightly slower while young; afterwards it depends on local conditions as to which of the two oaks reaches ultimately the greatest height.

e. Reproductive Power.

Oak commences producing full masts at an age of about 70 years; they occur every three to six years, and are heavy. On the whole, the power of reproduction by seed is good.

The reproduction by shoots is excellent; the shoots spring not only from the stool, but also from the trunk. Stools retain the power of reproduction for a very long time.

f. Character and Composition of Woods.

Oak is grown in pure woods, and in mixture with other species. Owing to the decided light requirement of the oak and its tendency to form a spreading crown, it opens out at a comparatively early age, generally between the 40th and 60th years, when raised in crowded woods; from that time onwards, it cannot afford sufficient shelter to the soil, which is liable to deteriorate during the long period required to produce large sized timber trees. Hence, oak woods should be underplanted when the process of opening out has set in, or the tree must be mixed with species capable of preserving the fertility of the soil. Amongst these, beech is best, then come hornbeam, lime, and silver fir; spruce is less suitable, but more so than was formerly believed; Weymouth pine has also been used.

Oak does splendidly in mixture with beech, attaining a

great height and a clear bole of considerable length. In some cases the oak holds its own against the beech, but in the majority of cases it is liable to be outgrown; in the latter case, the oak must be protected against the beech by lopping the latter, or placed in groups, or given a start of the beech, by raising it pure and bringing in the beech when the oak begins to thin out.

Where the locality does not suit the beech, the hornbeam frequently takes its place; instances are frost localities and sandy soils in low lands. The oak holds its own against the hornbeam.

When oak is mixed with silver fir, it requires a decided start, or it will after some time be outgrown and suppressed. This mixture was once recommended, but foresters have practically given it up of late years.

Spruce is less suited for permanent mixture with oak; the two species have a different character and demand different conditions of locality. At first, the oak grows faster, and afterwards the spruce. Frequently oak becomes stag headed when mixed or underplanted with spruce.

When grown as standards in coppice, the oak is frequently mixed with many other species, such as ash, maple, elm, birch, larch, and Scotch pine.

Oak coppice woods grown for the sake of the bark should be pure, so as to obtain the highest possible returns; if grown for other purposes, they are frequently mixed with a variety of other species, such as beech, hornbeam, ash, elm, maple, sweet chestnut, birch, hazel, willow, and aspen.

g. Silvicultural Systems.

Oak is equally well adapted for high forest or coppice, and for combinations of the two; the sessile oak is a little more suited for coppice than the pedunculate species, because it is somewhat less exacting as regards fertility of soil, reproduces better from the stool, and the bark is easier to peel. A mixture of oak in beech woods is the best system for the

production of superior oak trees, also high forest with a soil protection wood, or two-storied high forest; if trees of large diameter and moderate height are wanted, standards in coppice woods answer well.

h. Formation of Woods.

The oak is regenerated principally by sowing and planting, or by stool shoots in coppice, less frequently by natural regeneration by seed.

The acorns ripen in October (pedunculate early, sessile late), and fall shortly afterwards; they retain their germinating power for about six months. Good seed should show a germinating percentage of not less than 65. One pound contains about 130 acorns of the pedunculate species, and about 160 of the sessile oak.

Direct sowings are made in autumn or spring; as to the merits of the two seasons, see the remarks under beech (page 331). Spring sowings sprout after 4 to 6 weeks. About 550 pounds of acorns are required per acre for broadcast sowings; they are covered with about 1½ inches of soil. Direct sowing yields finer woods than planting.

Sowings in nurseries are generally made in drills, or the acorns are placed flush on the seed bed in rows, and covered with 1½ inches of soil. The seedlings should be pricked out when one year old; they are ready for planting after two years more; frequently older plants are used, which may have been pricked out a second time. Three years old plants may be placed 3 feet apart, and older plants proportionately further. The plants stand pruning well, both on the crown and roots. They are generally planted out in pits.

Seedling plants one year old are frequently planted into the forest, as they are likely to grow into better trees than pricked out plants; not less than 8,000 seedling plants should be planted to the acre, so as to induce an early struggle for existence.

In regenerating oak woods naturally by seed, the acorns

must frequently be brought artificially into the ground, either lightly hoeing the soil after the acorns have fallen, or by driving herds of swine through the woods. The seed trees are removed quickly, generally within a few years after the young crop has come up; otherwise the latter is likely to suffer from the shade of the mother trees. In the Spessart and other localities, oak is sown in groups of 1 to 10 acres in extent on the more favourable parts of beech woods, leaving a thin shelter-wood of the latter. As soon as the young crop of oaks is established, the shelter trees are removed, and the rest of the beech wood is then naturally regenerated for beech. In this way, the danger of the oak being suppressed by beech is avoided.

i. Tending.

Fertility of the Soil.—As already stated, pure oak high forest is rarely capable of preserving the fertility of the soil; hence, such woods must be underplanted with shade bearing, dense crowned species.

External Dangers.—Young oak suffers from late frosts, but such damage heals easily, owing to the great reproductive power of the tree. Oak suffers much from frost cracks. It is very storm firm. Snow and rime only break the branches, especially the lower ones.

Cattle and game nibble oak freely; red deer and mice peel the bark to some extent. Oak supports more insects than any other tree. Kaltenbach, in an incomplete list, enumerates over 500 species. The acorns may be destroyed by weevils (*Balaninus*), the young plants by wire-worm; the trees are frequently defoliated by *Tortrix viridana, Geometra brumata, Liparis monacha, Hybernia defoliaria,* and in South Europe by *Cnethocampa processionea;* also by cockchafers. Many weevils eat the buds. The bark is injured, and sickly trees are killed, by species of *Agrilus* and by *Scolytus intricatus.* The timber may be rendered valueless by the boring of *Cossus* larvæ, or those of *Longicorns,* especially in Central Europe, by

Cerambyx heros. Many gall-wasps attack the oak, chiefly ill grown, pollarded, or hedgerow trees; they are only harmful in nurseries.

The Mistletoe (*Loranthus europaeus*) is found on the branches. Fungi are numerous on oak, but the forester need not be frightened by them. Canker appears on the stem, but it seems as yet doubtful whether it is produced by a fungus (*Nectria ditissima*) or frost. White rot in the stem is produced by *Polyporus igniarus* and *Hydnum diversidens;* red rot with white strips by *Stereum hirsutum;* red rot with white spots by *Telephora perdix;* red, white, and yellow rot intermixed in elongated places by *Polyporus dryadeus.* Seedlings and young plants are dried up by *Rosellinia quercina.*

On the whole, it is remarkable that external dangers do not do much damage to oak. The attacks of *Tortrix viridana* have, however, much increased of late years, and whole oak woods may be seen leafless in the beginning of June, and until the second shoots appear towards the end of that month. This destruction of foliage causes a reduction of increment, but, as a rule, it does not otherwise affect the health of the trees much.

Pruning.—The oak stands pruning well, but care should be taken to remove the branches while small, so that the wounds may be quickly closed.

Thinning.—As pure oak woods are generally underplanted, the thinnings should be as follows:—During youth, say up to the age of 40 years, there should be only very light thinnings or none at all. Cleanings may be made to remove any undesirable species threatening the oak, such as birch, willows, and aspen. After this early period, the thinnings should gradually become heavy, so as to develop a limited number of fine trees which are to form the final crop, assisted by an underwood if possible of beech to shelter the soil.

Quercus rubra, the red oak, has been much recommended of late years. It is a native of eastern and central North America, between the 40th and 46th degrees of latitude, where

it grows on low land and hilly ground, requiring somewhat less heat than the European oak, and also a less fertile soil. The timber is used much in the same way as the European oak, but it is of a quality inferior to that of the latter; on this point, however, different opinions still prevail. Its specific gravity is about the same as that of sessile oak. The height and diameter growth is much quicker than that of the European oak for the first 50 years, but afterwards it falls off. The tree is light demanding. Reproductive power is good. It is a handsome tree, which is well suited for mixture with beech.

Quercus Cerris, the Turkey oak, is not of much silvicultural value. It is a tree of South Europe, which yields a heavy timber of a specific gravity of 1·1 on an average, but which is of inferior quality as compared with pedunculate and sessile oak. Its growth is somewhat more rapid, though it does not reach the same height or diameter.

Ash—*Fraxinus excelsior* (L.).

a. Utility.

The ash yields an excellent timber, hard, heavy and elastic, tough and durable; specific gravity when air dried, ·73. It is used for a great variety of purposes, by the joiner, carpenter, wheelwright, sievewright, basket maker, etc. It also yields a very good fuel. The leaves are good fodder.

b. Distribution.

Europe up to 62° latitude, also North Africa. It is indigenous in Great Britain and Ireland, going up to 1,350 feet in Yorkshire. In the Alps it is seen up to 4,000 feet.

c. Locality.

Climate.—Ash does not require much heat, but it is very tender against late frost, and also drought. It is light demanding, standing next to oak, but it bears somewhat

more shade in youth. It likes moist air, and is storm firm.

Soil.—Ash requires a deep, porous, moist and fertile soil. It is chiefly found in low lands, near rivers, and in the bottom or cool aspects of mountain valleys. Good loamy soils with some lime, also marls, suit it best; it avoids sandy and acid soils.

d. Shape and Development.

The ash has a straight stem, which divides into branches at about half its height; it is specially liable to fork. The crown is of moderate extent and thin during the first half of the tree's life; afterwards it becomes broader. The root system is extensive and deep going, with a tap-root; the tree requires much growing space below ground. It is a rapid height grower, especially during the first half of its life; during the second half it is liable to be outgrown by both beech and oak. It reaches a height of about 110 feet, and more under specially favourable conditions.

Ash does not attain a very large diameter. Its volume growth is smaller than that of oak; the average annual production per acre may be placed at 40 cubic feet quarter girth measurement.

The upper age limit of ash may be placed at 200 years; in economic forestry it is rarely worked under a rotation of more than 80 years.

e. Reproductive Power.

The tree commences producing full crops of seed when about 40 years old; they are somewhat light, and occur about every other year. The reproduction by seed is on the whole good.

If coppiced, the ash reproduces well from the stool, chiefly by stool shoots, but also by suckers, but the stools do not last very long. It also reproduces well when pollarded.

f. Character and Composition of Woods.

Ash appears in pure woods, but owing to its light foliage it is not suited to be so grown except in very favourable localities. It is much better adapted for mixing with other species, especially beech and also hornbeam. It is frequently found mixed with oak, alder, maple, elm, lime, sweet chestnut, willow, poplar, and hazel, especially in coppice with standards, or coppice only. In such mixtures, it generally holds its own against the other species. A mixture of ash and larch is undesirable, unless the latter is cut out at an early age.

g. Silvicultural Systems.

Ash is treated as high forest, coppice, pollards, and as standards in coppice. If found pure in high forest, it requires underplanting, like the oak, best with beech.

h. Formation of Woods.

Ash woods are generally formed by planting, rarely by direct sowing, sometimes by natural regeneration.

The seed ripens in October and falls during winter until spring; it retains its germinating power up to three years. Of good seed 55 per cent. should germinate. About 6,500 clean seeds go to the pound.

The seed germinates in the second spring, and should be treated like that of hornbeam (page 336).

For direct sowings, about 35 pounds of seed per acre are required. The seed should receive a covering of about $\frac{3}{4}$ of an inch.

In nurseries, the seed is generally sown in drills about March or April of the second year, after it has been lying imbedded in sand for 16 or 17 months; the seedlings will be ready for pricking out in the following spring, and they may remain one, two, or more years in the nursery lines, according to the required class of plants. It may be mentioned that the development of a suitable crown and stem can be regulated at

this period, by removing unnecessary buds and young shoots. Ash is usually planted in pits.

i. Tending.

Young plants are very liable to suffer from late and early frosts; hence, some shelter is useful. This, however, must not be heavy, as the ash is light demanding. They suffer much from browsing by cattle and deer, unless protected by a fence. Deer, rabbits, and mice also peel the stem.

Insects and fungi are not very formidable. The leaves of the ash tree are rarely injured except by *Geometra brumata*, and in Central Europe by the blister-beetle, *Lytta vesicatoria*. The shoots are sometimes much stunted by the larvæ of a Tineid moth, *Tinea curtisella*. The bark is sought and badly gnawed by the hornet. The *Cossidæ* readily attack it, *C. æsculi* preferring the saplings to any other food plant. The bark-beetles, *Hylesinus fraxini* and *crenatus*, kill sickly trees; the former also attacks the upper branches of healthy trees and kills them in a few years.

Cankerous spots in the bark may be caused by *Nectria ditissima*.

The thinnings of ash woods should be such as to enable the tree to lay on diameter increment, in other words to give it a liberal growing space at all times, and especially with advancing age.

Fraxinus americana, the American ash, found from Canada to Carolina, is now much planted in Europe. It demands a climate and soil similar to those of the European ash, but is perhaps satisfied with somewhat less fertility, and is somewhat less exposed to damage by late frosts, as the leaves appear a week or two later. The wood is heavier and somewhat more elastic than that of the European ash.

ELM—*Ulmus* (L.).

The following two species will here be noticed :—

(1.) the common elm, *Ulmus campestris*, Sm.

(2.) The Scotch, wych, or mountain elm, *Ulmus montana*, Sm.

a. Utility.

Elm yields a coarse timber which is hard, moderately heavy, difficult to split, very durable, even when exposed to alternate wet and dry. Specific gravity of air-dried common elm, mean, ·73, of mountain elm, ·69. It is used for a great variety of purposes in rural districts, by the carpenter, joiner, wheelwright, turner, boat-builder, and others. It yields a fair firewood, and the leaves are good fodder. The ashes yield excellent potash.

b. Distribution.

Common Elm.—Central and South Europe, North Africa, and Siberia; goes up to 2,500 feet in the Alps. It is found in England up to an elevation of 1,500 feet in Derbyshire, also in Ireland, rarer in Scotland. Introduced into Britain, where it does not, as a rule, bear fertile seed.

Wych Elm.—Europe and Siberia. Indigenous in Britain, going north to Sutherland, also in Ireland. Ascends to 1,300 feet in Yorkshire, and to 4,000 feet in the Alps.

c. Locality.

Climate.—Elm requires a mild climate, but is not sensitive to late frost. Wych elm requires somewhat less heat than the common elm. It is a light demanding tree, but less so than oak and ash. The common elm is only fairly storm firm, the wych elm more so; the branches of old trees are easily broken.

Soil.—Elm demands a deep, fairly porous, moist and fertile soil to do well; hence, it is mostly found on alluvial soils in low lands and valleys. The wych elm is somewhat less exacting than the common elm.

d. Shape and Development.

The elm divides into branches at about half its height. The crown of the common elm is narrow and tends upwards;

the wych elm has a broader crown. The root system consists of a tap-root with numerous side roots; at an advanced age the system becomes somewhat more shallow. It grows quicker than oak, but rather slower than ash, and reaches an ultimate height of about 110 feet; the common elm under specially favourable conditions up to 125 feet. It attains a considerable diameter,* and reaches an age of 400 years and more.

e. Reproductive Power.

The elm commences producing seed plentifully at the age of about 40 years. The crops are heavy and occur about every 2 or 3 years; in Britain the seed of the common elm very rarely ripens. On the whole, the reproductive power by seed is great. Both elms have a great reproductive power from the stool, there being stool shoots and suckers; they also reproduce well by stem shoots. Trees upwards of 40 years old, when cut over, still reproduce well from the stool.

f. Character and Composition of Woods.

Elm is not well suited for pure woods. It does much better mixed with beech and hornbeam; it is also grown with oak, ash, alder, and others, not unfrequently in coppice with standards. It holds its own against these species, except beech, which may outgrow it during the second half of life. If pure, elm should be underplanted like oak. It is much grown as a hedgerow tree.

g. Silvicultural Systems.

High forest, standards in coppice, coppice, and pollards.

h. Formation of Woods.

The elm is generally planted; the plants are either raised from seed, or they consist of suckers or layers. As the seed of the common elm does not ripen in Britain, it is generally propagated in the latter way in this country.

* The author has seen, at Schimsheim, in Rhenish Hessia, a common elm tree of 14 feet diameter measured at 3 feet from the ground.

The seed ripens in May to June and falls almost immediately; it keeps its germinating power only for a short time, and must be sown at once. If 30 per cent. germinate, it is considered good seed. There are about 60,000 seeds to the pound. In nurseries, the seed is best sown broadcast and very slightly covered with fine earth, one-tenth of an inch being sufficient; it germinates after 2—3 weeks. The seedlings may be placed in nursery lines in the following spring, and they are fit to be put out after another year, though they frequently remain longer in the nursery.

The methods of obtaining layers and suckers have been indicated on pages 230—31.

i. Tending.

The elm, being hardy, does not require much tending if grown mixed with other species. Cattle and deer do damage by browsing, but the damage is quickly healed. Insects and fungi do a moderate amount of damage. The elm suffers from two scale-insects, *Schizoneura lanigera* and *Lecanium vagabundum;* the latter lives on the stems of saplings, destroying large patches of bark. Elms have been much injured by two bark-beetles, *Hylesinus vittatus* in Central Europe, and *Scolytus Geoffroyi* (*destructor*, Ol.). The latter is exceedingly harmful to the unhealthy elms growing near large towns; it also attacks trees in the open country, selecting weak spots, generally the extremities of old branches at the summit of the tree, and working down the trunk year by year. Of *fungi* nothing need be mentioned.

Elm generally holds its own against the species with which it is usually mixed, except perhaps beech, but from middle age upwards it must be given a liberal growing space by thinning away the other species to a sufficient extent.

Sweet Chestnut—*Castanea vesca* (Gærtn.).

a. Utility.

The chestnut yields a fairly hard, moderately heavy timber, splits well, durable. Specific gravity air dried, ·61. Young

chestnut is said to be more durable as fencing posts than young oak. Afterwards, the tree is liable to become shaky, and the timber is less valuable than oak timber. Used for building, in carpentry, staves for wine casks, vine stakes, hop poles, pit timber, etc. It is not a very good firewood, but the charcoal is much appreciated by blacksmiths. The bark is used for tanning. The fruit is eaten.

b. Distribution.

It is indigenous in the south and south-west of Europe, in Asia Minor, the Caucasus, and Persia ; introduced into Britain, where the fruit does not always ripen. It rises to 2,800 feet in the Alps.

In its natural home, the chestnut is a tree of the lower hills and mountains ; rarely found in the low lands.

c. Locality.

Climate.—Requires a mild climate, is tender against late and early frost and also severe winter cold ; drought also does not suit it. Chestnut is a light demanding tree, but less so than oak. During youth it stands some shade, so that it thrives under Scotch pine woods. Later on in life it becomes more light demanding. It is storm firm.

Soil.—Chestnut likes a deep, porous, fresh and fertile soil. It can grow in rather dry soil if deep, but avoids wet localities. A loamy sand suits it best ; it does not like heavy or calcareous soils.

d. Shape and Development.

Chestnut has a straight stem, which, however, branches at a moderate height. If space permits, it produces a broad crown, which is fairly dense. The root system is deep going, resembling that of the oak.

The height growth during youth is somewhat more rapid than that of oak, but it does not reach quite the same height

as the latter. It attains a very large diameter,* and it is a long lived tree, reaching an age of some 400 years.

Its mean annual increment is greater than that of oak.

e. Reproductive Power.

Chestnut comes into full bearing at the age of about 50 years. Full seed years occur every 2 or 3 years, though some seed is produced almost annually.

The reproductive power from the stool is very great; even the stools of trees up to 100 years old, when cut over, yield shoots; the stools last a long time.

f. Character and Composition of Woods.

The chestnut is not very suitable for growing in pure woods as high forest, as it opens out about the same time as the oak, though not to the same extent. Such woods require under-planting. It is, however, grown pure as coppice. It does well in mixture with beech and oak as high forest; in coppice, it is grown mixed with many species, as beech, oak, ash, elm, maple, lime, birch, hazel, willow, aspen, etc.

g. Silvicultural Systems.

High forest, standards in coppice, but chiefly coppice. In Southern Europe, it is much grown as a fruit tree in open woods. As high forest, it is treated under a rotation generally not exceeding 100 years, as coppice under one of 5 to 30 years, according to the size of the required material.

h. Formation of Woods.

Direct sowing is done, but chiefly planting. The chestnuts ripen in October and fall immediately. They retain their germinating power for about 6 months. Of good chestnuts, not less than 60 per cent. should germinate. One pound contains about 100 chestnuts.

Direct sowings should be made in spring, as the chestnuts

* A chestnut tree on Mount Etna is reported to have a girth of about 200 feet (Döbner-Nobbe)

are liable to be eaten by mice if sown in autumn; they should not be sown too early, as the young seedlings are tender against late frosts. The chestnuts should be covered with about 1½ inches of soil; they germinate after 5 or 6 weeks.

The treatment of chestnut in nurseries is similar to that described for oak.

i. Tending.

Young chestnuts must be protected against late and early frosts, either by sheltering them artificially or by raising them in sheltered localities. They also require protection against cattle and deer, which browse them. Further on in life, chestnut suffers much from frost cracks and shakiness.

Damage by insects and fungi is not of much importance. The only part of the sweet chestnut, as a rule, liable to damage by insects is the fruit, the crop of which may be much lessened by the internal-feeding larvæ of species of *Carpocapsidæ* among the *Tortrices*.

The chestnut stands pruning well.

Thinnings are made as in the case of oak.

Maple—*Acer* (L.).

The following two species are grown as forest trees in Britain :—

(1.) The great maple, or sycamore, *Acer Pseudo-platanus*, L.

(2.) The Norway maple, *Acer platanoides*, L.

a. Utility.

The white or yellowish-white timber of the two maples is moderately heavy (sycamore, specific gravity, air dried, ·67, Norway maple, ·74), hard, fairly durable under cover, but of short duration in the open. It has great heating power, but is not an agreeable fuel for domestic purposes. It is used by the joiner, for finer wheelwright's work, carving, mathematical instruments, rollers in cotton mills, and a variety of other purposes. The leaves yield good fodder.

The timber of the sycamore is somewhat preferred to that of the Norway maple.

b. Distribution.

Sycamore.—Middle Europe and Western Asia. Goes higher in mountains than the beech; up to 5,000 feet in the Alps. Introduced into Britain.

Norway Maple.—Europe, Asia Minor and Caucasus. Goes further north than the sycamore, up to 62° of latitude; it does not go as high as the sycamore in mountains; to about 4,000 feet in the Alps. Not indigenous in Britain.

c. Locality.

Climate.—The maple generally makes small demands on the temperature, but it suffers somewhat from late frosts, and also from excessive heat; it is hardy as regards winter cold. It prefers moist air. As regards light requirement, it stands about half-way between light demanders and shade bearers. Maple is a storm firm tree. The Norway maple is adapted for cultivation by the seaside; it is more a tree of the plains than the sycamore; it also suffers less from late frosts.

Soil.—Maple requires a deep, fresh, and fertile soil; Norway maple can do with somewhat less fertile soil than sycamore, also with less moisture, but stands a higher degree of it than the other maple.

d. Shape and Development.

The stem of the maple, though straight, divides rather low down into branches; it forms a large oval crown if grown in the open, which is of moderate density. In crowded woods the maple develops a tall, cylindrical stem, with a small crown restricted to the upper part of the stem. The root system is deep going, somewhat less so in Norway maple. Maple at first shows quick height growth, which falls off comparatively early, so that it is liable to be passed by beech, though it may ultimately reach nearly the same height. Both

maples reach a large diameter, and an age of 400 years and more.

e. Reproductive Power.

Sycamore produces full crops of seed after the age of 40 years, Norway maple a few years earlier; they are not very heavy, and occur about every other year. On the whole, the reproductive power by seed is good; that from the stool is moderate, and the stools do not last long.

f. Character and Composition of Woods.

Though maple is fairly well adapted for pure woods, it is generally mixed with other species, especially beech, also oak, and even conifers.

g. Silvicultural Systems.

High forest, standards in coppice, and coppice.

h. Formation of Woods.

Maple is generally planted, though it reproduces naturally wherever it has a chance.

The seed ripens in September to October; it falls in October and into the winter months. The germinating power disappears rapidly after the following spring. Good seed should show a germinating percentage of at least 55. One pound of seed of sycamore contains about 5,000 seeds, of Norway maple somewhat more.

The best plan consists in bedding the seed, as in the case of ash and hornbeam, sowing it in drills in the spring, as soon as it shows signs of germinating; the seed should be covered at least to a depth of ¾ of an inch, but 1¼ inch is not too much. The cotyledons appear in that case after about 2 weeks, if the weather is warm. Seed kept over winter and sown in spring germinates after 4 to 6 weeks, and sometimes only in the second spring. The seedlings may be removed into nursery lines when one year old.

Maple is generally planted out in pits.

i. Tending.

Maple, while young, requires some protection against late frosts. It is browsed by deer, also sometimes peeled, but it is little injured by insects. The seedlings are sometimes destroyed by wireworm. The roots of saplings may be attacked by chafer-grubs, whose imagos may defoliate the tree, as well as the larvæ of *Acronycta aceris*. *Cossus æsculi* will kill young trees.

Fungi are of little importance. The black spots on the leaves are due to *Rhytisma acerinum*. *Phytophthora fagi* sometimes kills young seedlings.

Mistletoe is found on maple.

Pruning should be avoided.

Thinnings.—The maple should be given an ample growing space when the height growth begins to fall off.

COMMON ALDER—*Alnus glutinosa* (Gærtn.).

a. Utility.

The specific gravity of air dried wood is, on an average, ·53 The timber is soft, splits easily, does not last in the open, but well under water, and is used accordingly; it is also used for clog making, herring barrel staves, for cigar boxes, and cooperage. It yields an inferior fuel, but a charcoal well adapted for the manufacture of gunpowder, for which purpose, however, it is no longer much used. The bark is used for tanning.

b. Distribution.

It is found in most parts of Europe up to 63° of latitude, in Northern Africa, and in Western and Northern Asia. It is indigenous in Great Britain and Ireland. It goes up to 1,600 feet in the Scotch Highlands, and to about 3,500 in the Alps.

c. Locality.

Climate.—Alder requires little warmth, is fairly hardy against frost, but very sensitive to drought. It is a light

demanding tree, standing about on a par with elm, but somewhat below oak. It requires moist air, and suffers from snow and rime, which break the branches.

Soil.—Alder requires a porous, moist soil of at least middling depth. Moisture is specially wanted in the subsoil. Although it requires more moisture than the commoner forest trees, it does not thrive in stagnant water. It is at least moderately exacting as regards the chemical composition of the soil. It does best on sandy loam rich in humus, and thrives even on peat soil; cold clay and dry sand do not suit it. Alder is principally found along river banks in the low lands, and at the bottom of mountain valleys. It does not seem to be particular about aspect.

d. Shape and Development.

Alder develops a straight stem, which divides only in the upper part; the branches are of moderate size with a rather thin foliage. The root system consists of a number of deep going side roots, which branch in the subsoil and end in numerous fine rootlets. It is a quick grower, but rarely reaches a height of 75 feet, generally considerably less; it lives, as a rule, to an age not exceeding 150 years, only exceptionally longer. A mean annual increment of about 45 cubic feet quarter girth measurement per acre may be expected.

e. Reproductive Power.

Alder begins to seed fully at the age of about 30 years; the crops of seed are heavy, and they occur about every year or two. On the whole, the energy of reproduction by seed is moderate. The reproductive power from the stool is strong and enduring; the tree produces stool shoots.

f. Character and Composition of Woods.

Pure woods of alder are found in moist or wet localities, where a dense sheltering of the ground is either not essential, or even undesirable. It is also found in mixture with other

species, especially with ash, birch, elm, or oak, generally occupying the moister parts of the woods.

g. Silvicultural Systems.

Alder is mostly treated as coppice, either by itself or as underwood under standards. It is also found in high forest; in that case rarely pure but generally in mixture with other species. As coppice, it is treated under a rotation up to 40 years; in high forest under one of 50 to 80 years. Coppice shoots reach about the same height as seedling trees.

h. Formation of Woods.

Alder woods are generally formed by planting, and then either coppiced, or, if treated as high forest, replanted after cutting. The plants are sometimes raised from cuttings and layers, but generally from seed.

The seed ripens in October, and falls from November until spring. It maintains its germinating power for about one year; if 30 per cent. germinate, it is considered good seed, but frequently a much smaller percentage is fit to germinate. One pound contains about 250,000 seeds.

For direct sowings, about 15 pounds of seed would be required per acre, but such sowings are rarely made; the seeds should receive a light covering of about two-fifths of an inch, and they germinate, if sown in spring, after 4 to 5 weeks.

In nurseries, a moist part should be chosen for the seed beds; at any rate they must be kept moist after sowing. The seed is sown broadcast. When one year old, the seedlings may be pricked out, and left one or two years in the nursery lines.

The planting is mostly done in pits.

i. Tending.

Alder does not require much tending. When quite young, it is liable to suffer from frost lifting, owing to the moist condition of the soil where it is usually grown. This can be

prevented by covering the space between the plants; any plants actually lifted must be promptly put back into the ground.

Considerable danger may threaten alder from the drying up of the subsoil owing to a change in the level of the ground water. Such danger must, as far as practicable, be avoided, by preventing the water from being drained away. At the same time, inundation may do much damage, especially if it occurs after a wood has been coppiced, and if the water covers the stools, or if sheets of ice form over young plantations.

Insects and fungi do little damage. The foliage of alder may be injured by *Tortrix* larvæ, or by the plant-beetles, *Agelastica alni* and *Lina ænea*, both uncommon in England. The bark of young alders is attacked by a weevil, *Cryptorrhynchus lapathi*, which breeds in their stems. Older trees are bored by the *Cossidæ* and one or two *Sesias*.

Of fungi *Nectria ditissima* may cause cankerous formations, and *Polyporus sulphureus* red rot in the stem. *Exoascus borealis* causes witches' broom, and several other species of this genus are found on the leaves and flowers.

Alnus incana, the white or grey alder, is sometimes planted along the banks of rivers and in localities liable to inundation. The tree produces numerous suckers; hence, it has been used to cover spoil heaps. It is also employed in France in reboisement works. Its timber is, on the whole, of less value than that of the common alder.

BIRCH—*Betula alba* (L.).

a. Utility.

The timber is fairly heavy; specific gravity of air-dried wood, ·69; moderately hard, does not split well, of small durability; good firewood; is also converted into charcoal for the manufacture of gunpowder. The timber is used by joiners, wheelwrights, and for coarse carvings; in Britain extensively used for bobbins, also for herring barrels. The

branches, and still more young shoots and trees, are used for withes, brooms, etc. The bark is used for tanning and the manufacture of small vessels and boxes.

b. Distribution.

It is chiefly found in Northern and Eastern Europe; also in Northern Asia and in North America (a variety). In Europe between 40° to 70° latitude. It is indigenous in Great Britain and Ireland. The following two forms are distinguished:—*Betula verrucosa*, the silver birch; *Betula pubescens*, the common birch. The latter goes farther north and less far south than the former. The birch is a tree of the low lands, lower hills, and even mountains. It grows up to 2,500 feet in Scotland, in the Alps to over 5,000 feet.

c. Locality.

Climate.—It requires but a low temperature, and is absolutely frost hardy. It is highly light demanding, but likes moist air. To some extent thrown by storms. Suffers somewhat from snow and rime. It prefers south or west aspects, but is a most accommodating tree.

Soil.—Birch requires only a shallow soil, with a moderate amount of moisture; it is not exacting as regards mineral composition. Although loamy sand suits it best, it accommodates itself to all sorts of other soils. It is found on soils ranging from poor, dry, sandy soil to swampy ground, especially the *pubescens* form, but avoids stiff clay and calcareous soils.

d. Shape and Development.

The stem is generally wavy or undulating, and divided into branches in the upper part. The crown assumes an elliptic shape, and is thin. The branches are often drooping. The root system is weak and shallow.

It grows quickly from the beginning, but rarely reaches a height of 100 feet, generally not beyond 70 or 80 feet. Its volume growth is smaller than that of most other important forest trees. Its life seldom exceeds 120 years.

e. Reproductive Power.

Birch begins producing full crops of seed when about 25 years old; they recur every two years and sometimes annually, and are heavy. On the whole, the reproductive power by seed is very great. The light seed is easily carried about, and young birch springs up wherever there is room for it, owing to the accommodating power of the species.

The reproductive power from the stool is weak; the shoots spring chiefly from the root neck; the stools are liable to die after two or three rotations.

f. Character and Composition of Woods.

Owing to its thin crown and great light requirement, birch is not well suited for pure woods; nevertheless, it appears pure over extensive tracts in Northern Europe (Russia, Scandinavia, and Britain), owing to its great reproductive power and accommodating character, which enables it to grow in localities where other species would not thrive, or where it outstrips them. In such localities its preservation is justified.

In other localities it should be mixed with species with dense crowns, such as beech. It is not so well suited for mixture with conifers, as it injures them by the whip-like action of its slender branches.

g. Silvicultural Systems.

High forest, also standards in coppice; little suited for coppice. Excellent shelter wood over a tender species; planted in shelter belts and wind breaks. Useful for filling blanks in existing woods. It is treated under a rotation of 40 to 60 years in high forest, and of 15 to 20 years as coppice; for the production of withes, it may be cut over after 3 to 5 years, according to circumstances.

h. Formation of Woods.

They can be formed artificially or naturally. The seed ripens from August to October, according to locality, and

commences falling soon afterwards and until February. It maintains its germinating power for 6 to 12 months. It is considered good seed if 20 per cent. germinate. One pound of clean seed contains something like 800,000 seeds.

Direct sowing is rarely done. Broadcast sowings would require about 30 pounds of seed per acre, which should be very thinly covered, only about one-eighth of an inch. The seed germinates after 2 to 3 weeks, if sown immediately after ripening, and after 4 to 5 weeks, if sown in spring.

In nurseries, the seed is sown broadcast and covered by sprinkling a little earth over it. The one year old seedlings may be pricked out and left for one or two years in the nursery lines, according to requirements. On the Continent, one or two year old plants are used for forest planting.

Birch can easily be regenerated naturally under a very small number of mother trees. Generally, it appears wherever it has a chance of springing up, and the forester has more to fight against it than to favour it.

i. Tending.

Fertility of Soil.—Early opening out and a thin crown do not enable the birch to act beneficially upon the soil; hence, it should not be grown pure, except on localities where more valuable trees will not thrive.

External Dangers.—Birch, being very hardy, requires no tending against climatic influences; the damage done by snow, rime, and storms is moderate. It is less nibbled by cattle and deer than almost any other broad leaved tree. It is attacked by mistletoe.

Insects.—The leaves support a very large number of larvæ, which, as a rule, are not gregarious. Injury is occasionally caused by the following species:—*Liparis dispar*, and *monacha*; *Eriogaster lanestris*, *Pygæra bucephala*. *Rhynchites betulæ* and its allies cut and roll up the leaves. The young stems are injured or killed by the larvæ of species of *Agrilus*, *Sesia*, and by *Cossus æsculi*. The goat-moth, *C. ligniperda*, lives in

older trees, which are also liable in some localities in N. Europe to suffer from the burrows of a bark-beetle, *Scolytus Ratzeburgi.*

Birch has no serious enemies amongst fungi. *Exoascus turgidus* produces witches' broom; *Polyporus betulinus*, red rot; *Polyporus lævigatus*, white rot.

Birch is rarely pruned. Thinnings are regulated naturally, as the weaker individuals are speedily suppressed by a moderate number of dominant trees per acre. In mixed woods, the more valuable species require, during youth, to be protected against the birch, as the latter generally grows quicker.

Betula lenta, L., is a tree of eastern North America, which has been recommended. It reaches a height of 80 feet and more, and the timber is said to be superior to that of the European birch, especially for furniture. The wood is heavy (specific gravity, ·76), fairly hard, elastic, and lasting. The young tree is more exposed to damage by game than the European birch.

WILLOW—*Salix* (Tournef.).

Of the numerous species of Willow only the following four need be mentioned here:—

(*a.*) Common sallow, or goat willow, *Salix caprea*, L.
(*b.*) White willow, *Salix alba*, L.
(*c.*) Crack willow, or withy, *Salix fragilis*, L.
(*d.*) Common osier, *Salix viminalis*, L.

The willows yield a soft light timber which is little prized, except for some special purposes, as for cricket bats; their principal value consists in yielding withes and materials for basket work, cask hoops, etc. The wood is not good fuel, but may be converted into charcoal for the manufacture of gunpowder. The bark is used for tanning. The osier yields the largest quantity of material for basket work, but various other species are grown for the same purpose.

The suitability of willow timber for the manufacture of cricket bats depends chiefly on the manner of growth. Manufacturers demand timber with a "close" bark, and reject that with an "open" bark. The pieces fit for bats should have not less than 12 inches quarter girth at the small end. Such timber is sold for 5 to 7 shillings the cubic foot. The most suitable species are certain varieties of *Salix alba*.

a. Common Sallow.

The sallow occurs all over Europe, North and West Asia, Himalayas. It is found in Great Britain up to Inverness, and in Ireland. It ascends to 2,000 feet in the Highlands and to about 5,000 feet in the Alps.

It is a tree of the low lands and outer hills, prefers a fresh soil, but can do even with dry soil; appears on calcareous soils. The tree is little exacting in respect of climate, and hardy. It is light demanding, of quick growth, and has a thin crown which cannot do justice to the soil.

It is treated as coppice wood, under a rotation of 10 to 15 years, having a good reproductive power from the stool; yields firewood, withes and fascine wood. It appears plentifully in high forest, but is generally removed in the cleanings and early thinnings.

The seed of this willow ripens in May or June, and must be sown at once, as it does not preserve its germinating power. Sowings of willow are, however, never made in silviculture. The tree is propagated by cuttings. These are cut, from a foot in length and upwards, from the previous year's wood, though older wood may also be used. The cuttings may be placed into a nursery for one year, or planted out at once. Unless the soil is very loose, holes should be made, into which the cuttings are planted. The area should be kept clear of weeds, and the surface soil loosened between the cuttings.

It is nibbled by cattle and deer, and peeled by mice. This holds good for all four species.

b. White Willow.

Europe, up to the 62° of latitude, North Africa, North and West Asia, North-West India. It is planted in all parts of Great Britain and Ireland, generally along the banks of rivers. It likes fresh, loose soil, especially of a loamy nature, but is not very exacting; is light demanding, grows rapidly, has a thin crown, and is hardy.

The white willow is best adapted for pollarding (topping), less suited for coppice. It also appears in high forest amongst other species. As pollards, it is worked under a rotation of 3 to 6 years; the material is used for fascines, cask hoops, and basket work.

It is propagated by cuttings, which may be 5 and 6 feet long, so as to produce a tree in the shortest possible time.

c. Crack Willow.

Europe, North and West Asia. Planted along river banks and low land generally; likes moist or wet soil, especially loamy sands; light demanding, thin foliage; grows rapidly; hardy, but suffers from snow and rime; good power of reproduction by shoots.

It is suited for pollarding and coppice, and is treated like the white willow; the shoots are not suited for basket work, as they are liable to crack.

d. Common Osier.

Russia, North Asia; cultivated throughout Europe. It is extensively grown in osier beds, which are generally established along river banks and other low lying parts of the country, on loose, moist, sandy soil; it is, however, exacting as regards general fertility of the soil. It is light demanding, with a thin crown; grows rapidly; fairly hardy, but suffers sometimes from frost, insects, and fungi.

The osier is treated as coppice. The rotation depends on the desired material, and ranges from 1 to 6 and even

8 years. Material for fine basket work is obtained by cutting annually. Reproduction is powerful, but the stools do not last for more than perhaps 15 years, and frequently not so long, if cut every year.

The osier is propagated by cuttings as described for the common sallow. In England, the cuttings consist frequently of whole shoots, of which only about 1 foot of the lower end is inserted into the ground; they are planted immediately after cutting.

Insects and Fungi injurious to Willows.

Willows generally are injured by numerous insects, which are common to most species. The wood, chiefly of *Salix alba*, is much attacked by *Aromia moschata*, *Lamia textor*, and other Longicorn beetles, and by the goat-moth, *Cossus*. The leaves are attacked by various *Bombyces*, as *Liparis salicis* and *Pygæra bucephala*; by sawfly larvæ, and by plant-beetles, especially the species of *Phratora* and *Galeruca*. These are very injurious to *Salix viminalis*, as are the leaf binding larvæ of *Earias chlorana*. The twigs are injured by *Sesiidæ* and by gall-gnats (*Cecidomyidæ*). A weevil, *Cryptorrhynchus lapathi*, destroys the bark and shoots, especially of *S. viminalis*.

Of *fungi*, several species of *Melampsora* produce a rust which causes the leaves to die. *Polyporus sulphureus* produces red rot in the wood.

Poplar—*Populus* (Tournef.).

The following three species must be mentioned:—

(*a.*) Aspen, *Populus tremula*, L.

(*b.*) White poplar, or abele, *Populus alba*, L.

(*c.*) Black poplar, *Populus nigra*, L.

a. Aspen.

i. Utility.

The aspen yields a soft light timber, of small durability in the open; average specific gravity, ·51; heating power small. It is sometimes used under cover for buildings, for packing

and cigar cases, rough cooperage, inner work of carriages, manufacture of matches, and of paper. The charcoal is used in the manufacture of gunpowder. The bark is used in tanning and dyeing (for the latter purpose also the leaves).

ii. Distribution.

Europe, up to the 70° of latitude, North Africa, North Asia. Indigenous in Great Britain and Ireland. Ascends to 1,600 feet in Yorkshire; to 4,000 feet in the Tyrol. Found over extensive areas in North-East Europe.

iii. Locality.

Climate.—Hardy against frost and drought. Highly light demanding, likes moist air, subject to be thrown by storms.

Soil.—Grows almost anywhere, except on very poor dry sand; moist loamy sand, rich in humus, suits it best. It is generally very accommodating.

iv. Shape and Development.

It develops a tall stem with a thin crown, reaching a height of about 85 feet, more only under very favourable conditions. It is of quick growth and short lived, rarely reaching an age of more than 100 years.

v. Reproductive Power.

Great by seed; sends out numerous root suckers.

vi. Character and Composition of Woods, Silvicultural Systems.

Rarely pure. Usually appears in high forest in mixture with other species, also occasionally as standards in coppice. Generally cut out in thinnings, as it becomes ripe in about 50 to 60 years, or threatens to injure the more valuable species.

vii. Formation of Woods, Dangers, Tending.

Aspen is generally propagated by root suckers, sometimes by layers; cuttings strike less well. It springs up readily from seed in open spaces, and in young woods of other species. The young trees are nibbled by deer, also peeled. Subject to much injury by insects. Requires no special tending.

b. White Poplar.

Europe, North Africa, North and West Asia, N. W. Himalayas. Indigenous in Great Britain and Ireland. Timber light, soft; specific gravity, ·45; used for similar purposes as that of aspen, but more valued.

Found in low lands and river valleys; likes deep, loose, moist soil; more exacting than aspen. Growth quick, sometimes reaching a height of 100 feet and a diameter of 2 feet in 40—50 years; stem straight; is light demanding; foliage somewhat denser than that of aspen. Reproductive power good, especially root suckers.

Best propagated by root suckers, less well by cuttings. Treated as pollards, less suited for coppice. Occasionally standards in coppice.

c. Black Poplar.

Europe, North Asia; not indigenous in Britain, but planted.

Timber light, soft; specific gravity, ·45; most valued next to that of white poplar, and used for similar purposes.

Appears in low lands and river valleys. Thrives on any soil, if loose and moist; does not like heavy soils. Grows rapidly, developing a straight stem; light demanding; hardy. Its volume production is very rapid; hence, it is a very profitable tree to grow, whenever the locality suits it.

Reproductive power good by stool shoots and root suckers. Best propagated by cuttings of various length. Treated as pollards, sometimes standards in coppice.

Insects injurious to Poplars.

The leaves of young poplars of all species are much devoured by larvæ, which are not gregarious, except those of *Dicranura* and *Liparis salicis*. The plant-beetles, *Lina populi* and *tremulæ* (an aspen feeder), also attack them. A Longicorn beetle, *Saperda populnea*, breeds in the twigs of young aspens, causing gall-like swellings and crippling the growth of the plant. Its congener, *Saperda carcharias*, breeds in the stems,

chiefly of black poplar from 5 to 20 years old, and is a great hindrance in many places to growing the tree. Various clear-wing moths, especially *Sesia apiformis*, and the goat-moth, *Cossus*, feed in the wood, often in company with *Saperda*.

Of *fungi*, *Melampsora* species produce a rust on the leaves.

The mistletoe is frequently found on poplars.

Lime-Tree or Linden—*Tilia* (L.).

Two species of lime-tree have to be mentioned.

(1.) Small leaved lime-tree, *Tilia parvifolia*, Ehrh.

(2.) Broad leaved lime-tree, *Tilia grandifolia*, Ehrh.

The former is the more important forest tree. An intermediate species is *Tilia intermedia*, D.C., or *Tilia europæ*, L., in Britain called the common lime-tree.

a. Utility.

The wood of the lime-tree is very light and soft, little durable, and of small heating power. Specific gravity about ·52 for *Tilia parvifolia*, and ·49 for *Tilia grandifolia*.

The timber is not fit for building purposes, but is used for tool handles, by joiners and coach-builders, for carving, piano sounding boards, cigar boxes, and for paper manufacture; young shoots are used for withes. The charcoal is used as crayons and for the manufacture of gunpowder. The bark yields bast for ropes, mats, packing, etc. The flowers yield a medicinal tea.

The timber of the small leaved species is somewhat better than that of the broad leaved lime-tree.

b. Distribution.

The small leaved species occurs in Europe up to the 63° of latitude; North and West Asia; goes up to 2,800 feet in the Tyrol. The broad leaved species is indigenous in Middle Europe and West Asia; goes up to 3,300 feet in the Tyrol.

Neither species is indigenous in Britain.

c. Locality.

Climate.—The lime-tree is somewhat frost tender, and still more sensitive against drought. It is by some considered a light demander, by others a shade bearer; practically it occupies a middle position in this respect. It is fairly storm firm.

Soil.—Requires a deep, thoroughly fresh, if not moist, fertile soil. The small leaved lime-tree is somewhat less exacting as regards both climate and soil.

d. Shape and Development.

When grown in the open, the lime-tree forms a fairly tall tree with side branches coming low down the stem. In crowded woods it develops a tall cylindrical stem, with the crown reduced to its upper part. The root system is deep going. It is of quick height growth during youth, subsequently similar to beech, reaching about the same height. It attains a very large diameter and a very great age, 1,000 years and more, especially the broad leaved species.

e. Reproductive Power.

The lime-tree commences producing full crops of seed after the age of 30 years, and they occur about every other year, showing a fair reproduction by seed. Reproduction from the stool is excellent, and the stools last a long time.

f. Character and Composition of Woods.

The lime-tree is, owing to its dense foliage, well suited for pure woods, but, as the timber is of inferior quality, it is not so grown, except in some parts of North Eastern Europe (the small leaved species). As a rule it is found mixed with other broad leaved trees.

g. Silvicultural Systems.

High forest, and coppice either simple or under standards of other species. It makes a good soil protection wood, and is also pollarded.

h. Formation of Woods.

As the seed rarely ripens in Britain, it is generally propagated by layers (see page 230), but also by seed obtained from the Continent. The seed ripens in October, the small leaved species 1 to 2 weeks later than the other. The seed of the broad leaved species falls in November, that of the other species later on in winter. It retains its germinating power for two years. Of good seed, 50 per cent. should germinate. One pound of seed contains about the following number of seeds: small leaved species, 12,000; broad leaved species, 5,000. The seed germinates either in the first or second spring. If bedded in sand in the autumn and sown in spring, it generally sprouts in the same year. It is easy to transplant up to a considerable size.

i. Tending.

Though lime is somewhat sensitive against late frosts, the damage caused to it in this way is as a rule moderate. Cattle like the leaves.

There are no other dangers against which the tree requires special protection. Insects and fungi are of little importance. The special foe to the lime is the buff-tip moth, *Pygæra bucephala*, whose gregarious larvæ often strip it bare. Other species, as *Liparis dispar* (not in Britain) and *Biston hirtaria*, may do the same. The leaves are sometimes destroyed by a mite, *Tetranychus telarius*, which, occurring in vast numbers, sucks their juices. The cankerous places on the bark may be due to *Nectria ditissima*.

HAZEL—*Corylus Avellana* (L.).

a. Utility.

The hazel yields a soft, moderately heavy wood, which, if young, is very tough, but not durable. Specific gravity, air dried ·63. The young wood is used for fascines, withes, cask hoops, walking sticks and other purposes. Older wood is sometimes used by joiners and sieve makers. The charcoal

is used for gunpowder manufacture. The fruits are eaten; they yield an oil. The leaves are eaten by cattle.

b. Distribution.

Europe, up to the 67° of latitude, Northern Africa, temperate Asia. Indigenous in Britain; goes up to nearly 1,900 feet in the Highlands, and to 5,000 feet in the Alps.

c. Locality.

Climate.—Frost hardy, does not like great heat. Stands some shade.

Soil.—To grow well, hazel requires a porous, fresh soil, which need not be deep; it avoids swampy ground.

d. Shape and Development.

It grows quickly, is generally a shrub and sometimes a tree up to 30 feet high. Does not reach a great age, perhaps 70 to 80 years.

e. Reproductive Power.

It bears full crops almost every year, commencing at an age of about 10 years. The productive power from the stool is good, and the latter lasts long. The shoots start mostly below the surface.

f. Character of Woods.

It has a beneficial effect upon the soil.

g. Silvicultural Systems.

It is generally grown as coppice, as underwood under standards, soil protection wood under oak; also suitable for hedges.

h. Formation of Woods.

From seed, or by layers.

The fruits ripen in September, and fall from October onwards; they retain their germinating power for about six

months. The nuts must be well covered with earth and protected against mice.

i. Tending.

The young plants must be protected against cattle, deer and rabbits.

Hazel is not often seriously injured by insects. The caterpillars of some *Bombyces* and *Geometræ* thin the leaves occasionally. The species of *Balaninus* at times greatly reduce the crop of nuts.

The branches show cankerous places, which may be due to *Nectria ditissima.*

ROBINIA PSEUDO-ACACIA (L.).—THE ROBINIA OR FALSE ACACIA; LOCUST TREE.

a. Utility.

Wood is heavy, hard, elastic, very lasting, and good firewood; specific gravity, ·77. The timber is used for sleepers, mining timber, shipbuilding, machinery, by the joiner and carpenter. Makes good fencing posts and vine stakes. Leaves are good fodder.

b. Distribution.

United States, especially in the eastern States. Introduced into Europe about 300 years ago.

c. Locality.

Tender as regards frost, especially early autumn frosts. Stands drought well. Storm firm. Suffers from snow and rime. It is highly light demanding. A tree of the low lands and low hills. Thrives on almost any soil, if not too wet or too firm and acid; prefers light soils, like loamy sand or lime soils. Takes nitrogen from the air.

d. Shape and Development.

Grows quickly during youth, slower afterwards. Crown thin. Stem rarely straight.

e. Reproductive Power.

Commences bearing full crops of seed at the age of 25 years, about every 2 or 3 years. Seed ripens in October to November, falls from February onwards. Seed remains good for 2 to 3 years; it should show a germinating percentage of at least 50. About 20,000 seeds to the pound. Germinates after 2 to 3 weeks.

f. Character and Composition of Woods.

In high forest, not fit for pure woods, should be mixed with species of denser crowns. Most suitable for coppice. Standards in coppice with standards. Used for fixing steep slopes, and as a temporary mixture with other species on poor land, where it enriches the soil with nitrogen.

g. Insects and Fungi.

Suffers from the May cockchafer grubs and wireworm; also sometimes from *Nectria* species.

WALNUT—*Juglans regia* (L.).

a. Utility.

The timber is fairly hard and very lasting; specific gravity, ·68. Excellent timber for joiner, for furniture, and a variety of other articles. The fruit is eaten.

b. Distribution.

Its home is Asia, but planted in all the warmer parts of Europe. Goes up to 2,500 feet in the Alps.

c. Locality.

Very tender as regards early and late frosts; suffers also by strong winter frost. Storm firm. The tree stands a fair amount of shade. It likes the bottom of valleys and low hills, and requires deep, loose, fresh and fertile soils to do well, also a mild climate. It likes limestone soils.

d. Shape and Development.

Grows quickly while young; the stem divides into branches at a moderate height. It reaches a height of 80 to 100 feet; and a great age, 600 years and more.

e. Reproductive Power.

From the stool, good. The tree begins to bear fruit when about 20 years old, and does so every 2 to 3 years. The nuts ripen in September and fall very shortly afterwards; they keep their germinating power for about six months. An old tree will bear from 2,000 to 3,000 nuts.

f. Character and Composition of Woods.

Chiefly grown for the sake of the nuts; is found mixed with beech, where it must be protected against the latter; sometimes standards in coppice with standards.

g. Formation of Woods.

The tree is raised in nurseries and planted out when of sufficient size.

Juglans nigra, the black walnut of eastern North America, has been much recommended of late. It is said to suffer somewhat less from frost, and to be quite winter hard. Does well only in first-class localities like those mentioned for the common walnut, where it is expected to reach a considerably greater height than the latter, up to 150 feet. It is somewhat more of a forest tree than the common walnut, and should do well if mixed with beech. The timber is more highly prized than that of the European walnut.

Prunus serotina, Ehrh., is a native of eastern North America, found in low lands and low hills; likes a good moist soil, but is also satisfied with inferior soil, provided it is fresh. It reaches a height of 100 feet; light demanding; growth rapid. The wood is light, fairly hard; specific gravity ·58. It is an excellent wood for furniture, which fetches a high price. It has been recommended for planting in Europe; it is frost hard.

SILVER FIR—*Abies pectinata* (D.C.).

a. Utility.

The timber is light (specific gravity of air-dried wood on an average ·46); soft, easily worked, and splits well; lasts well in dry localities, less so if exposed to weather. Timber of quickly grown trees is less durable than that of slowly grown trees such as are produced in crowded woods. It is used for a great variety of purposes in Britain, principally as boards, planks, rafters, and small boxes for packing strawberries. Used for the manufacture of paper. Strasburg turpentine is obtained from this tree.

b. Distribution.

It is found naturally in temperate Europe between the 36° and 51° of latitude. It is not indigenous in Britain; said to have been introduced about 300 years ago. In its natural home it is a tree of the lower mountains, ascending to 2,500 feet in Central Germany, over 4,500 feet in the Alps, and 6,000 feet in the Pyrenees.

c. Locality.

Climate.—Silver fir requires a fairly warm climate. It is subject to injury by late and early frosts, and is also tender as regards drought. It stands a great amount of shade, quite as much as the beech, if not more—in fact, more than any other forest tree mentioned in this part. It requires a certain amount of moisture in the air, but not so much as spruce. Northern and eastern aspects suit it best. It is fairly storm firm.

Soil.—Silver fir requires a deep, fresh and fertile soil, not too binding. Loamy soils suit it best, though it will do well on sandy soils, if fresh. Dry or acid soils do not suit it.

d. Shape and Development.

The silver fir develops a straight and undivided stem, occasional forking excepted, with comparatively thin branches.

The crown maintains a conical shape until the height growth has been completed, when the top becomes flat; in free standing trees it extends almost down to the ground, and even in fully stocked woods to nearly one-half the length of the stem. It has a fairly deep going root system.

Silver fir is of very slow height growth during the first 10 to 15 years of life, then the rate increases to such an extent that it reaches ultimately a greater height than any other British forest tree except spruce and Douglas fir. Woods of an average height of 120 feet are frequently seen, and occasionally of 150 feet. In South-eastern Europe trees up to 200 feet high have been seen.

If grown in woods, the silver fir will not surpass 300 years, but instances are known of single trees having reached an age of 600 years.

In volume increment silver fir is probably only surpassed by the Douglas fir.

The following data represent the mean annual production under a rotation of 110 years :—

Quality of Locality.	Mean annual production per acre, in cubic feet.		
	Timber and Fuel.	Timber only, to 3 inches diameter on small end.	Timber according to quarter girth measurement.
I., or best ...	240	206	155
II., or middling ...	173	145	109
III., or lowest ...	114	93	70
Average	176	148	111

e. Reproductive Power.

Silver fir produces full crops of seed from the 70th year onwards. Such crops are but light, and in favourable localities they occur at intervals of 2 to 3 years. On the whole, the reproductive power by seed is not great. Reproduction from the stool may be said to be *nil*.

f. Character and Composition of Woods.

Silver fir is excellently suited for pure woods; it has a dense foliage, and maintains a cover overhead to an advanced age, under which a thick growth of moss springs up, thus preserving a suitable degree of moisture in the soil.

It also forms a suitable stock with which other timber trees, such as spruce, beech, larch, Scotch pine, oak, etc., may be mixed. It is most frequently found mixed with spruce, as it has the same shape and approximately the same height growth. Silver fir, being deeper rooted, protects the spruce from being thrown by storms. Another most excellent mixture is silver fir and beech, as they make similar demands on the locality. Oak in mixture with silver fir does well, provided the former has a decided start to prevent being outgrown. At one time, this mixture was recommended, but it has now been given up. Silver fir is a very useful species for under-planting oak, larch, and Scotch pine, when these species commence to thin out, while they afford to the young silver fir the necessary shelter against late and early frosts and drought.

g. Silvicultural Systems.

Silver fir is adapted only for high forest, more particularly for the shelter-wood systems with natural regeneration by seed. If it is to be grown on blanks, it requires nurses to protect it against frost and drought while young. It may be seen occasionally as standards in coppice, but this is not advisable, owing to its dense foliage. As it does not reproduce from the stool, it cannot be grown as coppice; it makes, however, good hedges.

Silver fir is generally worked under a rotation of 90 to 140 years.

h. Formation of Woods.

Silver fir is, even more than beech, adapted for natural regeneration under a shelter-wood. Direct sowing and

planting should be done under such a wood; if this is not available, it must be supplied artificially, otherwise the young trees will suffer from late and early frost, and possibly also from drought and insects, especially a scale insect.

The seed ripens in September to October, in England towards the end of the latter month. As the seed falls at once, the axis of the cone alone remaining on the tree, the cones should be gathered as soon as ripe. The seed rarely keeps its germinating power for more than six or seven months. If 40 per cent. germinate, it is considered good seed. One pound of seed contains about 8,000 clean grains without wings.

Direct sowings may be made in spring or autumn, the latter season being on the whole preferable, as the seed is difficult to keep. If spring sowings are decided on, the seed must be kept in an airy loft and occasionally turned. Spring sowings sprout after 3 to 4 weeks. About 40 pounds of seed per acre are required for broadcast sowings; it receives a covering of about two-thirds of an inch. Sowings in patches under the shelter of existing woods are more frequent than broadcast sowings.

In nurseries, the seed may be sown in drills, or broadcast; the seedlings should remain for two years in the seed bed, and two years and upwards in nursery lines. In England, they are rarely put out under five years old; the plants may be placed 3 to 4 feet apart. The young plants generally require protection against frost and drought.

The silver fir is best regenerated naturally under a shelter-wood, the selection and group system being perhaps even better suited to it than the uniform system. Of late years, a combination of the group and strip systems has found great favour. The process of regeneration is a slow one. In most mature silver fir woods groups of advance growth are found, where operations may be commenced. By removing the shelter trees standing over such advance growth, and gradually the adjoining trees, regeneration extends all round, and the groups expand until they ultimately merge into each other.

In this way, the regeneration period of a wood may extend over 30, 40, and even 50 years. The old trees, being gradually placed into an open position, increase rapidly in diameter, volume and value. At the same time, they should be removed when the young crop demands it.

i. *Tending.*

Fertility of Soil.—Silver fir, if treated properly, is an excellent preserver of the fertility of the soil.

External Dangers.—The young trees require shelter against frost and drought for 10 and sometimes even 20 years. This is given either by the mother trees or by an artificial shelter-wood of larch, Scotch pine, or birch. This period passed, the tree is comparatively free from danger. Storms and snow may do damage, but not nearly so much as in the case of spruce. Cattle and deer nibble it, and the latter sometimes peel it, but it heals such damage more easily than other conifers. Squirrels bite off the leading shoots.

Insects are, on the whole, not very destructive. Two species of *Tortrix* (*T. murinana* and *rufimitrana*) destroy the needles and shoots, especially in Central Europe. A weevil, *Pissodes piceæ*, peculiar to this species, is destructive chiefly to sickly trees. The wood-wasps (*Sirex*) and some *Tomicidæ* bore into the wood, especially when newly felled. A scale insect is likely to attack young silver fir, whenever it is grown without shelter. At Cooper's Hill, two sample areas of silver fir were planted in 1891, one in the open, and the other, only fifteen yards distant from the former, under a shelter-wood of larch. The young trees on the former area were crippled by the scale insect, while the insect was totally absent from the trees grown under shelter.

Mistletoe is frequently found on silver fir, perforating the wood and reducing its value.

Of *Fungi*, *Melampsorella Caryophyllacearum*, formerly *Æcidium elatinum*, must be mentioned, which causes witches' broom and canker on the silver fir; this evil occurs sometimes

on a large scale. To meet it, the diseased stems should be cut out as early as possible. Of other fungi, *Phytophthora fagi*, *Pestalozzia Hartigii*, *Armillarea mellea*, and *Fomes annosus* may be mentioned, but they do less damage than in the case of spruce.

The silver fir stands pruning well.

If silver fir is mixed with other species, it should be carefully watched, as it is liable to be outgrown and injured owing to its slow growth during early youth.

Thinnings rarely need commence before the 25th or 30th year; they should be light, until the woods enter the last third of their life, when they should be heavy, so as to cause the remaining trees to increase rapidly in diameter. Throughout the thinnings, and especially the early ones, all trees infected with canker should be removed, even if by so doing the leaf canopy should temporarily be interrupted; in many cases it may be possible to remove the witches' brooms before the stem has become infected.

Many other species of fir have been grown in Britain. Of these, the following deserve, perhaps, most attention from a silvicultural point of view:—

Abies Nordmanniana, Spachs, from the Caucasus.

Abies grandis, Lindley, from western North America.

Common or Norway Spruce *Picea excelsa* (Link.).

a. Utility.

The timber of the spruce is light, with an average specific gravity of ·45; soft and splits well; somewhat more durable than that of silver fir. It is known in Britain as white Baltic pine, the principal tree of the European timber trade, and is used for a great variety of purposes, chiefly in the shape of boards, planks, and scantlings. The timber grown in Britain is frequently of inferior quality, owing to its rapid growth in insufficiently stocked woods. It yields a fair fuel, and is extensively used for the manufacture of paper. The bark is used for tanning. The tree yields turpentine.

b. Distribution.

The spruce is found naturally in Europe from the 69th degree of latitude down to the Alps, at about 42°. It is a tree of the mountains, being found up to an elevation of about 6,000 feet in the Alps. On proceeding north, it gradually descends, until it is found near the sea shores of the Baltic as a tree even of the low lands. Nevertheless, in Norway it rises still to a considerable height. The tree has been introduced far beyond its natural limit. It is said to have been first planted in Britain in 1548.

c. Locality.

Climate. Spruce requires relatively little heat; it stands a considerable amount of winter frost, but it is somewhat tender as regards late frosts, though not nearly so much so as silver fir. It is very tender in respect of drought. It is a shade bearing tree, standing, amongst conifers, next to silver fir, though the latter bears considerably more shade. The beech, also, is more shade bearing than the spruce. These three species, together with hornbeam, are the principal shade bearing timber species of temperate Europe. Spruce demands moist air to do well; hence, in the centre of its natural home, it prefers north-easterly aspects. It is the least storm firm species of the trees mentioned in this book.

Soil.—Spruce is satisfied with a shallow soil of middling porosity, which must be at least fresh, and may be moist, or even wet, provided it is not actually swampy and acid. It does not stand inundation, and absolutely avoids dry soils. It is moderately exacting as regards the chemical composition of the soil, and reaches its greatest perfection on loams and shales.

d. Shape and Development.

Spruce develops a straight, undivided stem, with thin branches, which become somewhat drooping with advancing age. The crown retains a conical shape throughout life; in crowded woods, it is restricted to the upper third of the stem. Spruce has a shallow root system.

Spruce grows at first rather slowly, but faster than silver fir; when 10 to 15 years old its height growth becomes rapid, and it ultimately reaches the greatest height of the indigenous trees of Central Europe, 150 feet and more, with a diameter up to 5 feet.

In volume growth it is only surpassed by silver fir and Douglas fir.

The following mean annual production may be expected under a rotation of 80 years:—

Quality of Locality.	Mean annual production per acre in cubic feet.		
	Timber and Fuel.	Timber only, to 3 inches diameter at the small end.	Timber according to quarter girth measurement.
I., or best	234	200	150
II., or middling ...	143	112	84
III., or lowest ...	71	49	37
Average	149	120	90

Its maximum age as a forest tree is about 300 years.

e. Reproductive Power.

Spruce begins bearing full crops of seed after the age of 50 years; they are heavy, and, under favourable conditions, occur about every 3 to 5 years. On the whole, reproduction by seed is favourable, more so than that of the other shade bearing species. There is no reproduction from the stool.

f. Character and Composition of Woods.

Spruce occurs in extensive pure woods, for which it is well adapted; it has a dense foliage, and preserves a complete cover for a considerable time, in fact until near maturity. Under its shelter, a heavy growth of moss springs up, which keeps the soil moist; at the same time the shallow root system of the spruce is liable to drain the upper layers of the soil.

It is a suitable tree for mixture with many species, such as silver fir, beech, larch, and Scotch pine, but less so with oak,

which is liable to become stag headed in mixture with spruce. It is not so well suited for under planting as beech and silver fir. If mixed with silver fir and beech, it is apt to outgrow and injure them.

g. Silvicultural Systems.

Spruce is treated as high forest under the clear-cutting and shelter-wood systems; both succeed well, but the former somewhat better. In the case of the shelter-wood systems, the mother trees are liable to be thrown by storms. For the same reason, spruce is not suited for standards.

Spruce is treated under a rotation of 60 to 120 years. It makes excellent hedges, and is also much grown for wind breaks along the edges of woods.

h. Formation of Woods.

Spruce woods can be formed naturally or artificially, both methods being practised. Under ordinary circumstances, it does not require shelter when planted.

The seed ripens in October, and falls towards spring, the cones remaining on the tree for some time afterwards. It preserves its germinating power for 3 to 5 years, Of good seed, 75 per cent. should germinate. One pound of seed contains about 60,000 clean grains. Direct sowings should be made in spring; the seeds should receive a covering of half an inch of soil; they germinate after 3 to 5 weeks. About 10 pounds of clean seed per acre are required for broadcast sowings.

Sowings in nurseries may be done broadcast or in drills. British nurserymen prefer the former, sowing about ·6 of a pound of seed per 100 square feet of seed bed. The seedlings can be pricked out when one year old, but they are frequently left two years in the seed bed; after they have stood one or two years in nursery lines, they are put out into the forest. The plants may be placed 4 feet apart.

On the Continent, spruce is planted in a variety of

ways; as seedlings with or without balls of earth, or as transplants; either one plant may be placed into each planting spot, or sometimes several plants are put together, so-called *bunch-planting;* the latter method is now little followed.

Natural regeneration is effected both under shelter-woods, and on clear cuttings the seed coming from adjoining woods. If under a shelter-wood, the seeding cutting is made fairly strong, and the final stage is short as compared with beech and silver fir, because the young trees do not require so much shelter and are less shade bearing, while the mother trees are liable to be thrown by storms after the cover has been seriously interrupted.

In the extensive mixed forests of spruce and silver fir found on the Continent, the seeding cuttings are made with special reference to silver fir; when a sufficient regeneration of the latter has been effected, the spruce is frequently planted in when the shelter-wood has been removed, so as to establish a proper mixture in the young wood.

i. Tending.

Fertility of Soil.—Spruce is quite capable of preserving the fertility of the soil as long as the cover is not interrupted.

External Dangers.—Spruce is exposed to many dangers. From late frosts it suffers only to a moderate extent, but is very tender as regards dry winds and drought generally. Persistent cold winds also are liable to injure young spruce. Hence, it is essential to keep the edges of spruce woods as dense as possible. The tree is easily thrown by storms, and it suffers very extensively from snow and rime; either the crown is broken, or whole trees and groups of trees are thrown down.

The spruce has many insect foes, and recovers less readily from injury than the Scotch pine. The seedlings and young plants suffer like those of the Scotch pine, *Hylobius abietis* being a great danger. Many *Tortrices* live on the twigs and

needles; the chief devourer, however, is the nun, *Liparis monacha*, which has caused widespread destruction. The spruce-gall Aphis, *Chermes abietis*, cripples the shoots, which are also extensively hollowed out by *Hylurgus piniperda*. The bark-beetles, *Tomicus typographus* and its allies, are most destructive insects. They specially follow caterpillar attacks, and are perhaps more dreaded than any other forest insects of Europe.

Spruce is also much infested by *fungi*. Young seedlings are attacked by *Phytophthora fagi*, which kills large patches of them in nurseries. Young plants up to a few years old become yellow and succumb, owing to *Pestalozzia Hartigii*. *Fomes annosus* and *Armillarea mellea* attack the roots. Red rot is produced in the root and the stem by *Polyporus vaporarius*; white rot by *Polyporus fulvus* and *borealis*, and *Trametes pini*; green rot by *Peziza æruginosa*. There are many other species of minor importance.

Young spruce woods require watching, lest birch, aspen, and willow should settle in them and injure the spruce.

Pruning.—Spruce does not stand the pruning of green branches, the operation being generally followed by a falling off in height growth, and dry rot. Dry branches may be removed; in many cases it improves the quality of the timber considerably.

Thinnings generally commence at the age of 20 to 25 years; they should be light, and frequently repeated up to the age of 50 years. This is necessary, as snow breakage may occur during this period, followed by a considerable interruption of the cover. After the age of 50 years the thinnings may be heavier.

PICEA SITCHENSIS (Carr), THE MENZIES OR SITKA SPRUCE.

a. Utility.

The specific gravity of the timber is given as ·48, or slightly higher than that of the Norway spruce. The timber is soft; fairly firm. It has in Europe the same value as that of the

Norway spruce. It is said to make excellent light oars, for which purpose it is imported by the Admiralty.

b. Distribution.

Western North America, from California to Alaska.

c. Locality.

Suffers somewhat from late frosts when young, but not much; frost hard in winter. Cannot stand drought, but does not mind inundations.

As regards soil, the Menzies spruce is not particular, except that it seems to avoid lime soils. It requires a good measure of moisture in the soil, as well as a moist atmosphere; it grows on peaty soil, but does best on a fresh to moist sandy loam.

d. Shape and Development.

Height growth during the first few years (3–5) somewhat slow, but then much faster than that of the Norway spruce. It reaches in Washington an ultimate height of 200 to 300 feet, with a very large diameter. As far as can be judged at present, it is likely to produce as much volume as the Douglas fir, or nearly so. In its natural home a tree of over 700 years old has been observed. The root system is shallow.

e. Reproductive Power.

Is said to resemble the Norway spruce in this respect. The seed ripens in October. Germinating percentage about 55. One pound is reported to contain about 180,000 seeds. It is raised in nurseries in the same way as Norway spruce. It stands shade, but not quite so much as the Norway spruce.

f. Tending.

Owing to its spiky needles, it is somewhat less attacked by game. In how far it is liable to attacks by insects and fungi, cannot yet be stated. The May cockchafer and the pine weevil attack it, also *Armillarea mellea* and other fungi.

Picea alba (Lk.), the North American white spruce, has to some extent been grown in this country. It is a much smaller tree. Its treatment is similar to that of the Norway spruce; fully frost hard, and stands sea winds better than Norway spruce. It is believed to grow even on dry sand, provided the air is moist.

SCOTCH PINE—*Pinus silvestris* (L.).

a. Utility.

The timber has an average specific gravity, air dried, of ·55, soft, but somewhat harder than that of spruce and silver fir; durable if not grown too fast, and impregnated with turpentine; more durable than that of spruce and silver fir. The value of the timber depends much on the locality where it has been grown, the treatment of the woods, and the age of the trees; the timber of slow grown old trees, if sound, is far superior to that of fast grown or young trees. The proportion of heartwood is small, until an age of 70 to 80 years has been reached. It is used for a great variety of purposes in the shape of boards, planks, and scantling, for railway sleepers, mining props, and to some extent also for wood pulp. It is imported into Britain as red Baltic pine. A fair fuel. It yields turpentine. From the needles an aromatic oil is prepared.

b. Distribution.

It is found in Europe between latitude 37° and 70°, also in Asia. The countries round the Baltic and German Ocean are its centre of distribution. Indigenous in Great Britain and Ireland. It is eminently a tree of the low lands; prefers southern aspects in mountains. It ascends to 2,200 feet in Britain, about the same in Northern Germany, and up to about 6,000 feet in the Alps.

c. Locality.

Climate.—Scotch pine is hardy against frost and drought, but flourishes best in a fairly warm climate. It is light

demanding, standing in this respect between larch and oak. The degree to which it will bear shade is very limited, but it depends much on the climate in which it is grown. It prefers dry to moist air, but possesses an enormous power of accommodation in this as well as other respects. Scotch pine is a storm firm tree, but it suffers severely from snow and rime.

Soil.—Scotch pine requires a deep soil, which should be porous. Although it reaches its greatest perfection on fresh soil, it will grow under any conditions of moisture, from very dry soil to swampy ground. Sandy soils with a moderate admixture of loam suit it best, but it accommodates itself to any description of soil, from shifting sand to clay. It is not an exacting species as regards mineral substances in the soil.

d. Shape and Development.

The natural tendency of the tree is to divide its stem only in the upper part into a limited number of strong branches. In crowded woods, the crown is restricted to the uppermost part of the tree. The stem is not so straight as that of spruce or silver fir. Scotch pine develops a tap root, and a generally deep going root system.

Scotch pine grows quickly in youth and also afterwards, attaining, under favourable circumstances, an ultimate maximum height of about 120 feet; more only under exceptional conditions. Trees up to 150 feet have been measured. The shape and development differ enormously in different parts of the area over which it is found. The average height of crowded woods, grown on fertile soil and under a favourable climate, may run up to 100 feet. The upper limit of its life may be placed at 500 years.

As regards volume increment, it stands below silver fir, spruce, and larch, but above the broad leaved species except beech.

The average production is as follows, under a rotation of 80 years :—

Quality of Locality.	Mean annual production per acre in cubic feet.		
	Timber and Fuel.	Timber only, to 3 inches diameter at the small end.	Timber according to quarter girth measurement.
I., or best	146	122	91
II., or middling ...	90	74	55
III., or lowest ...	37	27	20
Average	91	74	55

The III. quality is very low, as Scotch pine can be grown on very inferior soil.

e. Reproductive Power.

Full seed years commence when the tree has passed an age of 30 years ; they are heavy, and occur about every third year. Reproduction by seed is favourable.

f. Character and Composition of Woods.

Scotch pine occurs in extensive pure woods, owing to its general usefulness and its accommodating power, less on account of its power to maintain the fertility of the soil. During youth and up to the age of 30 to 50 years, according to circumstances, Scotch pine is soil-improving, and maintains the moisture in the soil, owing to the cover overhead and the growth of moss on the ground. When that age has been reached, the woods begin to thin out, and they are no longer capable of doing justice to the soil; the moss is replaced by grass or heather, the humus disappears, and a suitable degree of moisture in the soil is endangered.

It is well suited for intermixture with beech and silver fir woods, also with Weymouth pine and spruce. It holds its own against these up to an advanced age. In the moist climate of Britain, it is also grown in mixture with larch and oak.

g. Silvicultural Systems.

Scotch pine is generally treated as high forest with clear cutting, exceptionally only under the shelter-wood systems. It is fairly suited for standards in high forest, as well as in coppice. It is extensively grown as a shelter-wood for frost tender species.

h. Formation of Woods.

Scotch pine may be sown or planted on clear cuttings, or regenerated naturally, either under an open shelter-wood or on cleared areas from adjoining woods. Planting is the usual method in Britain. No shelter is required by the young plants. On the Continent, it is much sown *in situ.*

The seed ripens in October of the second year, but does not fall until the following spring, so that in autumn three kinds of cones may be seen on the trees, namely 6 months old unripe cones, 18 months old just ripe, and empty cones of the previous crop. The germinating power is maintained for 2 to 4 years. Of good seed, not less than 70 per cent. should germinate. One pound of clean seed contains about 75,000 grains.

Direct sowings should be made in spring, the seeds being covered by about ½ an inch of earth. About 6 pounds of seed are required per acre for broadcast sowing; it germinates after three or four weeks.

Sowings in nurseries are mostly broadcast or in drills. British nurserymen sow broadcast about ·6 pound of seed per 100 square feet of seed-bed. The seedlings may be pricked out when one or two years old. In Britain, seedling plants are rarely put out into the forest; transplants are used which may have stood one or two years in the nursery lines; older plants are rarely used. On the Continent, seedlings are frequently put out directly into the forest. In Britain, notching is the usual method of planting, but peg and pit plantings are also done; three or four years old plants should be placed 3 feet

apart, on fertile soils perhaps 3 feet 6 inches. Seedling plants may be planted with a peg, or the vertical notching spade; they should be planted closer than older plants.

In the case of natural regeneration under an open shelter-wood, only a limited number of trees per acre, not more than 30, should be left, and these should be removed two or three years after the seeding has taken place. If the seed is to come from adjoining woods, the cleared area should not be broader than about the height of the trees, and it must be so situated that the seed is blown on to it. If regeneration does not occur within two or three years, sowing or planting must be done.

i. Tending.

Fertility of Soil.—Except in favourable localities, the fertility of the soil is liable to suffer after the Scotch pine has passed the age of 50 years; hence, it should be under-planted between the 20th and 40th year with beech, silver fir, Douglas fir, spruce, or Weymouth pine.

External Dangers.—Scotch pine requires no protection against frost or drought; frost lifting may, however, occur during the first year or two. It suffers, generally, very much from snow and rime, and Scotch pine woods are much exposed to fires; to protect them against the latter, regular fire traces must be cleared, and a strict watch kept during dry weather over the use of fire in the woods and in their vicinity. The tree is not much subject to be thrown by wind, except on a shallow soil over an impermeable stratum; its branches and top are, however, liable to be broken.

Scotch pine is nibbled by cattle and game, but rarely peeled. Rabbits do much damage by peeling the bark of young trees near the ground, and squirrels by peeling them later on in the upper part. The number of these animals should be reduced by shooting, or fencing or trapping in the case of rabbits.

Scotch pine is liable to a greater variety of insect injuries than any other tree, especially when grown on poor soil.

Seedlings are destroyed by wire-worms, *Tipula* larvæ, and millipedes, also by chafer grubs. Young plants (2 to 5 years) are injured by root-feeding bark beetles (*Hylastes*), and they are gnawed by numerous weevils, especially *Hylobius abietis*, which kills a large number. The needles are destroyed by the larvæ of *Liparis monacha*, *Fidonia*, *Trachea*, and other moths, *Lophyrus pini* and other sawflies; on the Continent by *Gastropacha pini*, which frequently kills the trees. *Retinia* larvæ cripple the terminal shoots, which are also thinned out by *Hylurgus piniperda*. Many weevils, *Pissodes*, *Magdalinus*, *Tomicus bidentatus*, etc., live in the bark and twigs. The *Siricidæ* and Longicorn beetles live in and destroy the wood.

Fungi prey upon Scotch pine to a very considerable extent. *Phytophthora fagi* kills very young seedlings. Young plants and trees up to an age of about 30 years lose their needles after becoming yellow or brown; the cause of this has not yet been satisfactorily explained, though in many cases a fungus (*Hysterium pinastri*) is present, and may occasion the disease, which is called "leave shedding," or *Schütte* in German. Both *Armillarea mellea* and *Fomes annosus* do much damage. *Peridermium pini* causes canker by drying up the bark and cambium all round the tree, and kills the part above it; such trees are called "foxy" in England. White rot is produced by *Trametes pini*; red rot by *Polyporus vaporarius* and *mollis*; a bluish black rot by *Cerastoma piliferum*.

Pruning of green branches cannot be recommended; dry branches may be removed. Occlusion is slow.

Thinnings may be commenced between the ages of 15 to 20 years, according to circumstances; they should be light and frequently repeated until middle age. If it is then decided to underplant the Scotch pine, the thinnings must become heavier; if not, they should continue to be moderate, so as to preserve a complete cover. At the same time, trees are constantly dying off from various causes, such as insects and fungi, or they are broken by snow and rime. Such trees must

be removed as speedily as possible; hence, dry wood cuttings are more frequent in Scotch pine woods than in any other.

BLACK OR AUSTRIAN PINE—*Pinus Laricio* (Poir.), var. *austriaca.*

a. Utility.

The Austrian pine yields a light soft wood, which is very rich in turpentine, and very durable. Specific gravity, air dried, ·56. It is a good building timber, and in its natural home the tree yields more turpentine than any other European conifer.

b. Distribution.

Lower Austria, Hungary, Croatia, Dalmatia and the south-eastern Alps, where it ascends to about 4,500 feet. Introduced into Britain during the last century.

c. Locality.

Climate.—The tree is frost hardy and not sensitive to drought. It demands light, but stands more shade than the Scotch pine, standing between that tree and the Weymouth pine. It prefers dry air, and is storm firm. Suffers much from snow and rime, even more than Scotch pine.

Soil.—It likes a moderately deep, porous and fairly moist soil, which need not be fertile. In its natural home, it is chiefly found on calcareous soils, especially over dolomite formations, but it thrives almost equally well on any other formation. Its demands on fertility and moisture are even less than those of the Scotch pine, so that it grows on shallow, dry soils, even on rocks. It is considered one of the least exacting of the European timber trees.

d. Shape and Development.

The tree develops a straight stem; the crown is similar to that of the Scotch pine, but fuller, stronger and denser. Its

height growth is somewhat slower than that of the Scotch pine, and it does not reach the same height, at any rate when grown beyond its natural home. The root system is strong, and similar to that of Scotch pine. The volume growth is smaller. It is said to attain a great age in its natural home.

e. Reproductive Power.

The tree commences producing full crops of seed after it has passed an age of 30 years, and they occur every 2 to 3 years.

f. Character and Composition of Woods.

The Austrian pine appears in extensive pure woods in its natural home, and it is better suited to be so grown than the Scotch pine, because it has a denser crown, which shades the soil better, preserves a complete leaf canopy to a more advanced age, and acts beneficially on the fertility of the locality. It can be mixed with the same species as Scotch pine, but demands more protection against being outgrown and suppressed. It does not require under-planting to the same extent as Scotch pine.

g. Silvicultural Systems.

High forest with clear cutting, but also the shelter-wood systems. It can be used as nurses over and between tender species; makes a good wind break along the edges of woods.

h. Formation of Woods.

Planting is the rule, but sowing and natural regeneration under a shelter-wood, or by adjoining woods, are also practised.

The seed ripens at the end of October in the second year, and falls towards and during the following spring. It retains its germinating power for 2 to 4 years. Of good seed 70 per cent. should be capable of germinating. About 23,000 clean seeds go to the pound.

The treatment of the seed and seedlings in the nursery is the same as for the Scotch pine.

i. Tending.

This is similar to that of the Scotch pine. The Austrian pine is exposed to the same dangers as the Scotch pine, but in a less degree; from snow and rime, however, it suffers somewhat more. It has the same insect enemies as Scotch pine, but is less frequently injured. A snail (*Bulimus delictus*) is a special foe to young plants, which it kills by eating the last year's needles in spring.

Fungi are the same as those found on the Scotch pine, but they do less damage.

CORSICAN PINE—*Pinus Laricio*, (Poir.) var *Corsicana*.

a. Utility.

Similar to that of the Austrian pine.

b. Distribution.

Corsica, Sicily, Calabria, Spain, Greece, South Russia, generally the south of Europe. Introduced into England about the year 1815. In its natural home, the Corsican pine is a tree of the mountains.

c. Locality.

Climate.—The tree is hardy in respect of early and late frosts, but less so as regards winter frost beyond its natural distribution. It thrives very well in the climate of Great Britain and Ireland. It is more light demanding than the Austrian pine; very hardy against drought, and resists sea spray better than almost any other species grown in Britain. Suffers much from snow and rime. Storm firm.

Soil.—It prefers a loose, fresh, calcareous soil or a loamy sand with a well drained subsoil, but it is not very particular; its demands on the fertility of the soil being very moderate.

d. Shape and Development.

The tree develops in England a straight stem, and it grows very rapidly in height, much more so than the Austrian pine. As far as experience shows, it reaches a much greater height, and is altogether a more desirable tree for planting in Britain than the Austrian pine. In its natural home it is said to reach a height of 150 feet. The root system is similar to that of Scotch pine, but not quite so strong or deep going.

e. Reproductive Power.

The tree commences to bear full crops of seed at the age of 25 to 30 years (in its natural home).

f. Character of Woods, Systems, Formation of Woods.

Similar to what has been said regarding the Austrian pine. Owing to its more rapid height growth in England, it generally holds its own against other species. Planting is the rule in England. One pound of seed contains about 32,000 grains, of which 70 per cent. should germinate.

g. Tending.

Similar to that of Austrian pine. Game, and especially rabbits, attack it much less than the Scotch pine. The tree suffers less than Scotch pine from abnormal leaf-shedding (*Schütte*).

WEYMOUTH PINE—*Pinus Strobus* (L.). (The White Pine of North America.)

a. Utility.

The Weymouth pine yields a soft light wood, of which enormous quantities are used in North America, and exported to Europe and other countries as American "white pine." The timber produced in Europe has a specific gravity of ·45, and is moderately durable. It is used in building, as boards and planks by joiners, carpenters, carriage builders, for matches, toys, paper manufacture, and a great variety of other

purposes. It is less valuable than the timber of the Scotch pine, and if grown in this country has about the same value as spruce timber.

b. Distribution.

The Weymouth pine is a native of the eastern parts of North America, where it is found between latitudes 36° and 50°. It was introduced into England in 1705, and has since been planted in various European countries.* In the Alps, it is now found up to 4,000 feet elevation.

c. Locality.

The following notes are based on experience gained in Europe :—

Climate.—The Weymouth pine makes moderate demands on temperature; it is hardy as regards winter, late and early frosts, and also drought. As regards light requirement, it stands half-way between light demanders and shade bearers. It is storm firm, and resists snow and rime well.

Soil.—It has been found to do best on deep, porous, fresh, loamy sands, but accommodates itself to dry poor soils, as well as to moderately swampy ground; it seems, however, to avoid calcareous soils. It resembles in these respects the Scotch pine, but demands perhaps a little more moisture in the soil as well as in the air, and is generally somewhat more exacting.

d. Shape and Development.

Weymouth pine develops a straight and undivided stem, with a fairly dense crown, which in crowded woods is restricted to the upper part of the stem.

During the first three or four years, it grows more slowly in height than the Scotch pine, which it generally catches up by the eighth or tenth year, when it keeps ahead of it, reaching a height of 120 feet or even more. In America, trees of

* According to Brandis it is not improbable that it was grown in Paris in the 16th century.

150 feet in height are frequently seen. Grown in crowded woods, it produces a cylindrical stem, but when grown in the open it tapers considerably. Its volume growth is considerably greater than that of Scotch pine. The root system is deep going, similar to that of Scotch pine. It is said to reach an age of 400 years in its natural home.

e. Reproductive Power.

The tree commences bearing full crops of seed when about 30 years old; these occur every two or three years, but a certain quantity of seed is produced almost every year.

f. Character and Composition of Woods.

In its natural home, the Weymouth pine appears in pure woods over considerable areas, but even more frequently is found mixed with other species, especially broad leaved trees. It is well suited for pure woods, as it has a fairly dense crown, maintains a sufficient leaf canopy until towards maturity, and preserves a favourable layer of humus and moss on the ground. In Europe, it is grown chiefly with Scotch pine, spruce, larch, and silver fir, when it generally holds its own. It is well suited for mixture with beech; it also appears in pure woods.

g. Silvicultural Systems.

High forest with clear cutting; fairly suited for underplanting oak on sandy soils, and also larch and Scotch pine; well suited for filling up blanks in young woods. It is less suited for standards in coppice, or as nurses over and between tender species.

h. Formation of Woods.

Planting is the rule, the seed being frequently too expensive and unreliable for direct sowings. The natural regeneration of the tree has been found to be very slow in Europe.

The seed ripens in September or October of the second year, and falls almost immediately. It retains its germinating power for 2 to 3 years. Of good seed, 50 per cent should be fit to germinate. One pound of seed contains about 23,000 grains. The raising of plants in nurseries is similar to that described for Scotch pine. As Weymouth pine plants are more costly than those of Scotch pine, they are generally treated with more care in transplanting, being as a rule placed into pits about 4 feet apart.

i. *Tending.*

Weymouth pine preserves the fertility of the soil. It requires protection against cattle and deer. Damage by insects is, according to present experience, not of much importance. Young plants are injured by a Coccid, *Chermes strobi*, and older ones by the gnawing and breeding of a weevil, *Pissodes pini*, as well as by a woolly aphis, *Cryptococcus*, sp. A bark beetle, *Tomicus bidentatus*, is occasionally injurious.

The Weymouth pine suffers from many of the fungi which attack Scotch pine, but in a less degree. *Armillarea mellea* and *Fomes annosus*, however, do more damage, as they frequently kill young trees of this species. Of late years, the damage done by *Peridermium strobi* has increased so much that the cultivation of the tree has altogether become of doubtful expediency.

The woods should be kept crowded so as to kill off the lower branches; hence, thinnings must be light until the height growth falls off. The dry branches remain for a long time on the stem, and it is desirable to remove them. Cutting off green branches cannot be recommended, because it causes the stems to grow unevenly.

Pinus Banksiana, Laude, a tree of eastern North America, has been recommended for soils so poor, that no other species will grow on them, whether it be moving sand or moist and even swampy ground. It is a quick grower from the beginning, but does not reach an ultimate height of more than about

70 feet. Entirely frost hard, and stands drought. The timber is not equal to that of the Scotch pine.

The Common Larch—*Larix europaea* (D.C.).

a. Utility.

The timber is moderately heavy; average specific gravity air dried, ·62; soft; splits fairly well; very durable, lasting longer than any other coniferous timber grown in Britain; it yields good firewood.

Larch is the best coniferous timber grown in Britain, for construction above and below ground; it is also used for ship-building. In Britain it is used for a great variety of purposes; it is much prized for railway sleepers, and mining purposes, and makes an excellent fencewood. Its price per cubic foot is generally about double that of Scotch pine timber. The bark is used for tanning and dyeing. It yields Venetian turpentine.

b. Distribution.

The homes of the larch are the Alps, the Carpathian and Moravian mountains, and also Poland. It has been cultivated in many countries, so that it is now found all over Europe between about the 42nd and 58th degrees of latitude. Larch is a true mountain tree; it is generally found in the Alps between 3,000 and 6,000 feet elevation, but goes up to over 7,000, that is to say, to the upper limit of tree growth. It is said to have been introduced into Britain at the beginning of the seventeenth century. Its cultivation in Scotland was commenced about the year 1725, when the Duke of Athol began planting it over extensive areas. It is found in the Highlands up to about 2,000 feet elevation, though its cultivation above 1,500 feet does not pay under present conditions.

c. Locality.

Climate.—Larch can do with a lower mean annual temperature than any other timber tree mentioned in this part. It

suffers from drought, is hardy against frost in its natural home, but liable to suffer somewhat from late frosts in low lands owing to its very early sprouting in spring. It is highly light demanding, and requires to have its head free throughout life. The climatic conditions required by larch have been much discussed. The majority of foresters believe that it prefers a dry atmosphere, a free and airy position, and northern and eastern aspects. It is more storm firm than almost any other conifer.

Soil.—Larch requires a deep, fairly porous, and moderately fresh soil; it avoids wet as well as dry soil. It is fairly exacting as regards the general fertility of the soil; loamy soil containing a good proportion of potash and lime suits it best; in its natural home, it is much found on stony soils, provided they are fresh.

The natural home of the larch enjoys only a short growing season, with a late and very short spring and comparatively hot, clear summer. These are conditions which seem to suit it. Britain, on the other hand, shows a much longer growing season, especially a long spring, a moister atmosphere, and a more cloudy summer—in other words, conditions which are altogether different from those prevailing in the natural home of the larch. It is not astonishing, therefore, that this valuable tree, although it grows most vigorously, suffers excessively from disease in Britain, as will be indicated further on.

d. Shape and Development.

Larch has an undivided stem, with a conical, thin crown; where the tree is exposed to wind, the lower part of the stem is frequently curved. In crowded woods, the branches are restricted to the uppermost part of the stem. It develops a tap root and generally a fairly deep going root system.

It is a quick height grower from the beginning and until it has reached nearly its full height, which may under favourable circumstances be placed at about 120 feet, though it grows higher under specially favourable conditions. As regards

volume increment, it stands between the firs and the pines. The average annual production under a rotation of 70 years may be placed at 80 cubic feet quarter girth measurement, provided the tree is planted on a locality generally suited to its requirements.

Ordinarily, it would not exceed an age of 300 years, though in the Alps it is said to reach sometimes double that age.

e. Reproductive Power.

Full seed years commence at the age of about 30 years; they are light, and may be expected every 3 to 5 years. A certain quantity of seed is produced almost every year. On the whole, the reproductive power by seed is moderate.

Larch possesses a certain power of reproduction by shoots, but this is of no practical value in silviculture.

f. Character and Composition of Woods.

Larch preserves a sufficient cover overhead only for a limited period, generally not exceeding 30 years, when it begins to thin out, admitting sun and air currents, which cause the fallen needles to decompose quickly, and the previous growth of moss to make way for grass. Hence, it is not suited for pure woods except on fertile soils or under specially favourable climatic conditions. It is far preferable to mix larch into other species with a dense foliage, such as beech and silver fir, against which it holds its own; or with Douglas fir, at any rate as a temporary mixture. In Britain, it is also mixed with oak, chestnut and Scotch pine. These mixtures are not good ones in themselves; if they are nevertheless employed, the reason is to be found in the fact that these three species are more valuable as timber trees than the above mentioned shade bearing species, and because in the moist climate of Britain a departure from the rules, which guide the forester in arranging mixtures, is more permissible than in dry Continental countries.

Whenever larch is grown pure, it should be under-planted

at the age of 15 to 30 years with a shade bearing species. Of these, beech is certainly the best, but as it is not always remunerative, other species have been used and suggested, such as silver fir, spruce, Sitka spruce, Douglas fir, *Thuia plicata*, *Tsuga Albertiana*, *Abies grandis*, and others.

g. Silvicultural Systems.

Larch is treated as high forest, as standards over coppice, and it is frequently grown as a shelter-wood over and between tender species. In high forest, it may be treated under a rotation of 60 years and upwards, according to the size of timber required. It is useful to fill blanks in existing woods, owing to its rapid growth.

h. Formation of Woods.

Larch may be planted on clear cuttings; rarely sown; in favourable localities it can also be naturally regenerated. Care in the selection of sites is essential, to prevent disease being brought about by unfavourable soil and climate.

The seed ripens in October or November, and begins to fall in the following spring; some of it remains in the cones until the spring of the second year, or even longer. The empty cones remain for several years on the trees. The germinating power is maintained from 2 to 4 years. If 35 per cent. germinate, it is considered good seed. One pound of seed contains about 70,000 clean grains.

Direct sowings are made in spring, about 14 pounds of seed per acre being required for broadcast sowings; it receives a covering of about one-third of an inch, and it germinates after three or four weeks, if the seed is fresh; old seed germinates very irregularly. Direct sowings are rarely made.

In nurseries, the seed may be sown broadcast or in drills. British nurserymen generally sow broadcast, about 1 pound of seed per 100 square feet of seed-bed. The seedlings are pricked out when one year old, or not at all. Plantings are

done with two-year-old seedlings, or with transplants after they have stood one or two years in the nursery lines. Older plants are rarely used. In Britain, the method of planting is generally notching: pit planting is also done. Planting must be done early in spring or in autumn, as the larch sprouts very early. The plants need not be placed closer than 4 feet apart.

Owing to its great light requirement, the tree is not really suited for natural regeneration by seed; but if this is attempted, the mother trees must be placed far apart, or the area clear cut in strips, allowing the seed to fall on them from adjoining woods. The method is only successful under favourable circumstances. At any rate, a second seed year should not be awaited, but all areas not stocked by the first seed year should be planted up.

Owing to the great spread of the larch blister, the tree should in future be planted only on localities which are thoroughly suited to it, or still better, mixed into woods of other species, especially beech.

i. Tending.

Fertility of Soil. Pure woods protect the soil sufficiently only for about 25 to 30 years: hence they should be underplanted.

External Dangers.—In its natural home, larch is hardy; it suffers little from late frosts, and also not much from drought. The damage done by snow and rime is of moderate extent, and the tree is very storm firm. In Britain, it is not so storm firm, especially if the soil should be saturated with water at the time of a gale; it also suffers somewhat more from late frosts, because it sprouts much earlier.

Roebuck and deer do a great deal of damage to larch by injuring the bark, which is also peeled by rabbits. Squirrels peel the top shoots. Hence, the tree should be protected against these animals by fencing and shooting.

Larch is much exposed to attacks by insects and fungi,

and these dangers are much greater in countries where it has been artificially introduced. The larch is especially attacked by minute moths, as *Coleophora laricella*, which hollows out the needles, and *Argyresthia laevigatella*, and several *Tortrices*. Of late years, *Nematus Erichsonii* has done much damage. The "larch-bug," *Chermes laricis*, is very injurious. Numerous bark beetles live in the larch in common with other conifers.

Fungi.—*Phytophthora fagi* kills the young seedlings. *Dasyscypha calycina* eats away the bark and cambium, causing canker; this disease has now become so prevalent in many parts of Britain that the further production of the tree has become altogether problematic. *Armillarea mellea* kills the roots; *Trametes pini* destroys the wood, leaving white spots; *Polyporus sulphureus* produces red rot.

Pruning. The larch stands pruning well, but the operation affords an entrance for fungi, especially *Dasyscypha calycina*; hence, it should be done very sparingly. It is much better to grow the larch so that the lower branches die off and fall naturally.

Thinnings must begin early. They should be light until the time has come for under-planting, when they must be heavy, leaving only healthy, vigorous, well-formed trees as the overwood which are to develop into large timber trees.

Of late, the Japanese larch, *Larix leptolepis*, has been much recommended. It is liked by many foresters, because it grows much quicker during the first 10 years or so, and it is also a handsome tree during that time. There is, however, no proof that it will do better than the European larch in the long run. On the contrary, there are indications that the latter catches up and passes it in height at the age of about 25 or 30 years, and that it is less branchy and straighter at that age. Again, canker has already been observed on the Japanese larch, as well as *Armillarea mellea*. Under these circumstances, there is no justification for believing that the substitution of the Japanese for the common larch will ultimately be an advantage.

Larix sibirica, the Siberian larch, is said to be satisfied with less good soil, to grow very straight, and to be less light demanding than the Tyrolese larch. On the other hand, it sprouts so early in this country that it is bound to suffer much from late frost. The author has seen it sprout in Bagley Wood, near Oxford, in the commencement of February.

Larix occidentalis, Nuttall, the western larch of North America, is said to reach a height of 180 to 200 feet with a diameter of 7 feet. It is found in the humid parts between the Rocky Mountains in British Columbia and Montana and the Cascade Mountains in Washington and Oregon. It reaches its greatest development in Montana. It appears between 2,500 and 6,000 feet elevation, requiring a fair measure of moisture. Its most common companions are Douglas fir, *Pinus ponderosa*, also *Tsuga Albertiana*, *Abies grandis*, and *Thuia plicata*. The timber is said to be of excellent quality. Endeavours are being made to introduce the tree on a larger scale into this country. The difficulty is that the seed falls immediately on ripening. Offers have been made to introduce it by sending seedlings, one year old, by fast steamers.

Douglas Fir—*Pseudotsuga Douglasii* (Carr).

(The Red Fir or Oregon Pine of North America.)

The Douglas fir is a native of the western part of North America, where it is found between latitudes 22° and 55° and from the Pacific coast to the east of the Rocky Mountains. There are two varieties, the *P. Douglasii* and *P. glauca*. The latter grows in a dry climate at high elevations in the Rocky Mountains, and is a smaller tree than the former, which occurs in the moist climate of the Pacific coast region. *P. glauca* is generally called the Colorado Douglas, while the other far more important variety is known as the Pacific or Vancouver Douglas. It is in that island and the adjoining coast districts that it reaches its highest development. It is found growing, according to locality, with the western

larch, the Californian red wood, Lawson's cypress, *Thuia plicata*; also silver firs, hemlocks, Sitka spruce, *Tsuga*, and others. The tree is considered the most valuable forest tree of North America, owing to its rapid growth, great dimensions, and the excellence of its timber. The latter is said to be equal to that of larch, while trees of over 300 feet in height, with a diameter up to 12 feet, are said to exist. More than one tree has been measured containing as much as 8,000 cubic feet of timber. In favourable situations, an acre may contain from 30,000 to 50,000 cubic feet of useful timber. The tree was introduced into Britain in 1827, and the experience so far gained singles it out as a most promising timber tree for this country.

The silvicultural data at present available are not yet sufficient to give a complete set of notes on the treatment of the Douglas fir in Britain. Numerous experimental plantations have been established in this country and on the Continent, some of which are upwards of 50 years old (apart from single trees or groups of greater age), and the following remarks are based upon observations made in these by the author, on the information supplied by Dr. H. Mayr, in his interesting works on "The Forests of North America," 1890, and "Fremdländische Wald and Park Bäume," 1906, and on the detailed account of this tree given in "The Trees of Great Britain and Ireland," by Elwes and Henry.

a. Locality.

The Douglas fir reaches its greatest perfection on the slopes and in the moist valleys of the Cascade Mountains in Oregon and Washington, in the coast districts of British Columbia and on Vancouver Island, approximately between the 40th and 50th degrees of latitude. These territories have an annual rainfall of about 65 inches, with a moist atmosphere, the climate being comparatively mild. As regards soil, it appears that a deep, fertile, and at least fresh, sandy loam suits the tree best. Under the most favourable conditions, it here attains a height

of about 300 feet. It seems to avoid stiff clay and also poor sandy soils, as well as chalk soils.

In the mountains of Montana, with a comparatively small rainfall of about 24 inches and a dry atmosphere, the Douglas fir reaches, if grown on the most suitable soil, a height not exceeding 150 feet, which, however, is also the limit in the coast districts, if the tree is grown on moderately fertile soil. On poor soil, even in the latter districts, the maximum height is frequently found to be 100 feet, or even less.

From these data it appears that the Douglas fir, if it is to do well, requires a moist climate and a deep, fertile, fresh or moist soil, especially light loam. It accommodates itself to a different climate and soil, but the height growth falls off in due proportion. It will do well only in sheltered positions, where it is not exposed to strong winds.

In its natural home the Douglas fir is said to be very hardy; in Montana it is exposed to great winter cold, and is found growing without shelter. In the coast districts, with a long growing season, it is said to suffer from early frost. In Britain it has on the whole been found hardy. It suffers somewhat from late frost, and also from early autumn frost occurring before the shoots have ripened. As to any difference in this respect between the two varieties, experience so far obtained is somewhat contradictory.

As regards damage by strong winds, the experience gained in Britain is somewhat alarming. Many trees have been blown down in Scotland, even in regular woods. In Bagley Wood, near Oxford, trees planted 11 years ago and 30 feet high were thrown in December, 1909. Even the plants in a plantation made 3 years ago were laid low three times during the winter of 1909—10, although they enjoyed a fair amount of shelter in the west and south. In the author's opinion, the tree is slow in developing a sufficient root system in Britain, so that it is easily thrown by wind, especially during wet weather. Even if not thrown, the leading shoots suffer much; they are either broken or bent. In Britain, the tree

should be planted only on thoroughly sheltered localities, best in the middle of woods consisting of a storm firm species, where the trees are well sheltered until they reach a considerable height and have developed a proper root system. In this respect, the very rapid growth of Douglas fir is against its successful cultivation on an extensive scale.

German foresters seem to consider the Douglas fir to be a moderately light demanding species. The author is more inclined to class it as a moderate shade bearer, standing near spruce.

b. Shape and Development.

The Douglas fir develops a straight undivided stem, except that in some localities the first 6 feet from the ground are curved. Grown in the open, the crown covers the whole stem and comes down almost to the ground; the stems of such trees are very tapering. If grown in crowded woods in its natural home, the lowest portion of the stem is exceptionally stout; the crown forms a sharp cone confined to the upper half of the stem, whilst the bole is described as of a remarkably cylindrical shape, at least as much as that of the European silver fir. A regular wood,* which the author examined in 1888, was 32 years old; in this, all the trees were excessively tapering, giving a form factor † of ·39 for timber only (over 3 inches diameter at the thin end). Since then, the form factor has risen to ·44.

The growth of the Douglas fir is exceedingly fast. At the same time, it varies enormously according to climate and soil. According to Mayr, a wood 80 years old and grown under the most favourable conditions showed an average height of about 133 feet, or an average annual height growth of nearly 20 inches. The Taymount plantation shows during the first 32 years an average height growth of about 22 inches.

In Montana, according to Mayr, the Douglas fir shows a

* Taymount, on the estate of the Earl of Mansfield, Scotland; area = 8 acres.

† For "Form Factor," see Volume III.

height growth of about 10 inches on an annual average, or about one-half of that in the coast districts. Under any circumstances, as far as experience goes at present, the Douglas fir, if planted in suitable localities, outgrows all European timber trees. The tree also attains a great diameter; the average diameter of mature trees, 200 feet high, in the coast districts is given as about 6 feet, and in Montana as about 2½ feet. It follows that the volume increment is very great. Experience up to date shows that it exceeds the fastest growing of European trees to a considerable extent, as the following data will show:—The Taymount plantation, carefully measured by the author in 1888, yielded the following data:—

Age of plantation = 28 years (age of the plants when put out, 4 years).

Number of trees per acre . . .	= 202
Mean diameter	= 12 inches
Mean height	= 60 feet
Volume in the round, excluding all material under 3 inches diameter .	= 3,738 cubic feet
Mean annual production . . .	= 133 " "

equal to 100 cubic feet quarter girth measurement.

The plantation was measured by Elwes in 1904, with the following result:—

Age of plantation	= 44 years
Estimated volume per acre . .	= 5,000 cubic feet
Average annual production . .	= 114 " "

The Earl of Mansfield had the whole plantation measured in 1908, when the following data were obtained:—

Age of plantation	= 48 years
Volume of timber per acre . . .	= 6,432 cubic feet

equal to an average annual production of 134 cubic feet.

The above figures do not include the yield of thinnings, regarding which no data are available; they may, however, be estimated at 30 per cent. of the present stock, so that the total

production during the first 48 years would amount to 8,361 cubic feet, equal to 174 cubic feet annually.

These results agree very well with those obtained by Earl Ducie near Tortsmouth, and by the Duke of Bedford in Devonshire.

It has been stated above that in the Pacific coast districts as much as 30,000 to 50,000, or say 40,000, cubic feet have been found on an acre. Considering that such woods are from 300 to 500 years old, it follows that the average production, as far as the final yield is concerned, is not greater than that of the Taymount plantation. Such enormous accumulations are of no practical value in this country, because nobody would think of waiting 300 to 500 years to obtain them. Moreover, there are unmistakable indications that the rate of growth of Douglas fir in this country is falling off at a comparatively early age, and that the timber is not likely to be of the same quality as that imported from America, unless the trees are allowed to reach a very great age. After careful consideration, the author is of opinion that the Douglas fir, though developing more rapidly during the first 50 years, is not likely to give very much better results in the long run than the silver fir does in the Jura, Vosges, and Black Forest. The late Mr. M'Corquodale, who planted the Taymount plantation and watched it for more than 30 years, held the opinion that the silver fir, if grown and treated in the proper way, would be the most useful and profitable tree to plant in this country, an opinion verbally expressed by him to the author in 1888. Until now, the silver fir has been so frequently a failure in Britain, because it has been planted on cleared ground instead of under shelter. If the latter method is adopted in future, much better results are likely to be obtained, a statement which is supported by the author's experience in the Cooper's Hill experimental plantations.

The Taymount plantation consists of the Pacific variety. The Colorado variety is not likely to yield anything like the above-mentioned results.

c. *Reproductive Power.*

Little is known about this, beyond that the trees grown in Britain produce seed freely, which has been used for rearing the younger plantations. In its natural home it is said to commence bearing seed when 10 years old.

d. *Character and Composition of Woods.*

Douglas fir, grown in crowded woods, produces a complete cover overhead, and seems well adapted to be grown in pure woods; as far as can be judged at present, it is likely to maintain a complete leaf canopy to a sufficiently advanced age to produce large sized timber. It is, however, liable to suffer from storms in Britain; at any rate, the leading shoots are always injured, unless the tree is grown in a thoroughly sheltered position.

Under these circumstances, the best results will probably be obtained by mixing it with other species. As it stands a moderate amount of shade and grows very rapidly, it should be planted under or between larch or Scotch pine. The larch may be planted pure, and, when from 15 to 30 years old, it should be strongly thinned, only healthy, vigorous trees being left, and under-planted with Douglas fir. Care must be taken to give to the Douglas fir sufficient light. The latter will reach timber size at the same time as the larch. The Douglas fir will shelter the soil between the larch, while the latter will afford the necessary protection to the leading shoots of the former. In this way, the Douglas fir can be grown in localities where it could not successfully be reared pure. At the same time, under this treatment very high returns may be expected.

The mixture of Scotch pine and Douglas fir may be arranged in the same way; but the under-planting may be postponed for another 10 years, and the Scotch pine must be less numerous than in the case of the larch.

Another method, which is likely to yield satisfactory results,

is to grow Douglas fir and larch *in alternate rows*, 4 feet apart in each direction. The larch will give a valuable early return, leaving a pure wood of Douglas fir, or one mixed with a limited number of larch trees, if the latter are not attacked by canker.

Instead of alternate rows of Douglas fir and larch, one row of Douglas fir may alternate with three rows of larch. Of the latter two rows would disappear in the thinnings, leaving alternate rows of Douglas and larch 8 feet apart. Subsequent thinnings would reduce the distance in the lines to, say, 8 feet, when about 680 trees would be left for further thinnings and the final crop.

e. Silvicultural Systems.

The Douglas fir seems suitable only for simple high forest; it suffers too much from wind to be grown as a standard in coppice.

f. Formation of Woods.

At present the seed is very expensive, so that direct sowings are out of the question. No experience has as yet been gained regarding natural regeneration. For the present, only planting is practised.

The seed* and seedlings are treated in the same manner as those of the spruce. The seedlings must, however, receive lateral shelter or light top shelter where late frosts are feared. They may be pricked out when one or two years old, and planted out into the forest after they have stood one or two years in nursery lines; their development is very rapid, similar to that of larch, and they need not be placed nearer than 4 feet apart. It is not desirable to use plants more than three years old for planting in the forest.

g. Tending.

Douglas fir seems quite capable of preserving the fertility of the soil.

* A pound of seed received from Mr. Conrad Appel, Darmstadt, contained about 40,000 grains, which produced 8,000 healthy seedlings.

How much the tree is likely to suffer from external dangers in Britain will depend on further experience. So far it is certain that it suffers somewhat from late frosts while young, but is hardy afterwards. Dry winds are not likely to suit it. Strong winds injure the leading shoots, and throw the tree unless it is mixed with other storm firm species.

Deer and roebuck are detrimental to the Douglas fir, more especially on account of their peeling the bark.

It is not possible to say at present in how far Douglas fir is likely to suffer from insects in Europe. It is attacked by a number of those which prey on the indigenous conifers, but further experience must show the extent to which it is likely to suffer from such attacks. Of fungi, *Botrytis Douglasii* kills the young shoots, and *Armillarea mellea* and *Fomes annosus* have been found on the tree.

The thinnings of Douglas fir woods should be light for a considerable period, so as to cause the lower branches to die off and to encourage the formation of cylindrical boles.

THUIA PLICATA (DON)—THE GIANT THUIA.

The timber is light, soft, and very durable; specific gravity said to be about ·38. It is extensively used, in its natural home, for construction in the interiors of houses, for canoes, shingles to an enormous extent, fencing posts, and many other purposes.

This tree is, next to the Douglas fir, the most important timber tree in Northern Oregon, Washington, and British Columbia. Its local name is cedar, or red cedar. It goes up to 6,000 feet.

It suffers from late frost and frost lifting when quite small. The tips of branches are liable to dry up in spring; it cannot stand drought. The tree is storm firm. It requires a moist soil and a moist atmosphere. A deep loamy sand suits it best, but it is not exacting as regards the fertility of the soil. It is a shade bearer.

The height growth is slow during the first few years, after that very rapid. On the coast and in Vancouver Island, it reaches a height of 200 feet, with a diameter up to perhaps 10 feet.

The seed ripens in October and falls soon afterwards. The tree begins bearing seed at an age of 15 to 20 years. Seed years recur frequently, and the production of seed is considerable. The seedlings are easy to rear. They should be pricked out when two years old, and they may be transferred into the forest either in early autumn or late spring.

Deer, roebuck, and hares injure the young trees, though not to a great extent. Mice gnaw the bark. It is reported from the Continent that *Pestalozzia funerea* kills the branches, especially if the tree is grown on unsuitable localities, but Elwes reports that he has not noticed the fungus in England. It is reported, however, that Thuia suffers in its natural home from two species of *Pestalozzia.*

It will probably be necessary to keep the young woods dense, as the lower branches seem to be very slow in dying and dropping off.

Chamæcyparis Lawsoniana (Parl.)—Lawson's Cypress.

The timber of this tree is light, soft, and very durable; specific gravity, ·46. In its natural home, it is used for construction, in shipbuilding, fencing, piles in swampy ground, etc.

It is a tree of western North America, at about 40° of latitude, where it is found in the low lands and hills. After the age of about five years, the tree is frost hardy in Europe, but sensitive as regards drought. It bears a fair amount of shade. It likes a fresh loamy sand, or sandy loam, but is also satisfied with inferior soils.

The rate of growth is slow during the first few years, then more active, so that the tree reaches a final height of about 170 feet in its natural home.

Deer attack it, but only to a moderate extent.

Hylobius abietis do damage while the tree is young;

afterwards it seems to be free from insect attacks. *Armillarea mellea* and *Pestalozzia funerea* do damage.

The tree is suited for high forest. It has also been recommended for under-planting oak, Scotch pine and larch.

TSUGA ALBERTIANA—THE WESTERN HEMLOCK.

This is a large tree, attaining a height of over 200 feet. It is found on the west coast of North America, attaining its best development on the coasts of Washington and Oregon. It is said to thrive on any soil except chalk, limestone, and heavy clay, to love moisture, but requiring a well-drained soil and a sheltered situation. The seed ripens in England. The rate of growth is slow during the first four or five years, afterwards fast. In America, the timber is used in the shape of boards and for construction. According to Sargent, it is light, hard, and more durable than the timber of other hemlocks. The bark is said to be the most valuable tanning material produced on the west coast of North America.

The tree has been used for under-planting larch woods at Novar in Scotland, and has done very well so far. On the whole, it deserves a trial on an adequate scale.

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